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OAK RIDGE
NATIONAL
LABORATORY

MARTIN MARIETTA

# Overview of the Biomedical and Environmental Programs at the Oak Ridge National Laboratory

Compiled and Edited by:
H. A. Pfuderer
J. B. Moody

July 1981



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# OVERVIEW

# OF THE

# BIOMEDICAL AND ENVIRONMENTAL PROGRAMS

# OAK RIDGE NATIONAL LABORATORY

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OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
DEPARTMENT OF ENERGY

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## INTRODUCTION

A major objective of the biomedical and environmental research at the Oak Ridge National Laboratory is to provide information on environmental, health, and safety considerations that can be utilized in the formulation and implementation of energy technology decisions. Research is directed at securing information required for an understanding of both the short- and long-term consequences of the processes involved in new energy technologies. Investigation of the mechanisms responsible for biological and ecological damage caused by substances associated with energy production and of repair mechanisms is a necessary component of this research.

Figure 1 gives the percentage of funding from the Department of Energy that is used to study the health and environmental consequences of each of the energy technologies. The emphasis in biomedical and environmental programs has shifted from nuclear to fossil and other nonnuclear energy programs and basic and multitechnology related programs. The programs in fossil are primarily related to coal and coal conversion, but also include oil and oil shale. Other nonnuclear programs include solar, geothermal, conservation, and fusion.

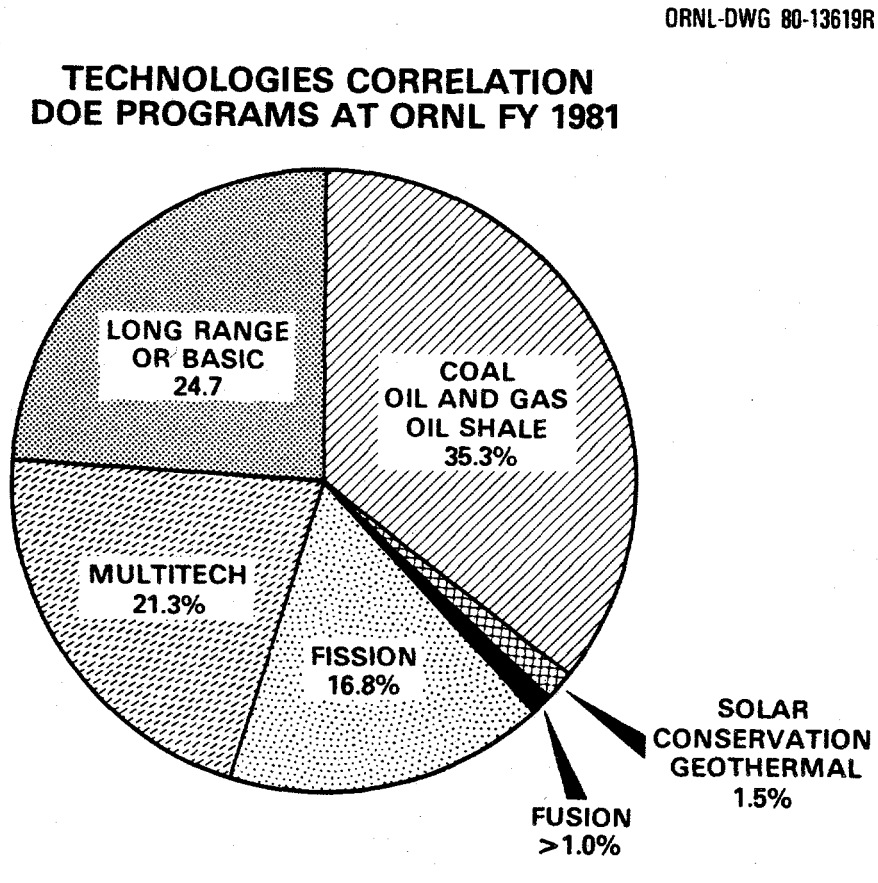



Figure 1

Overview and Assessment (HA 01)

ORNL staff provide technical support to DOE environmental assessments and assistance in DOE compliance with the National Environmental Policy Act and other environmental statutes and regulations with funding from the DOE Assistant Secretary for Environmental Protection, Safety, and Emergency Preparedness. In order to promote accurate, complete, and timely compliance of DOE programs, ORNL staff are: (1) preparing additional generic and technology-specific guidelines for environmental reports and procurement; (2) providing technical assistance to DOE on environmental matters related to DOE's role in performing cooperative agency responsibilities; and (3) providing technical assistance to DOE in the preparation of environmental guidelines or regulations implementing new legislation or executive orders. ORNL research involves: (1) data analysis with recommendations for immediate improvements in existing economic, energy, and environmental assessment capabilities; (2) development of new designs to meet criteria modeling needs; and (3) development of new modeling approaches to address important economic, energy, and environmental issues.

Laboratory-scale work is directed at providing the initial information needed for developing and evaluating the feasibility of alternative control technologies for application to coal conversion processes. Investigations which identify the key environmental parameters (such as Eh and pH) affecting mobility of trace organic contaminants and solid residues from fossil technologies are being conducted to insure timely development of cost-effective control/management strategies. Field investigations are directed at obtaining information on the performance of coal control technologies as they are applied to large-scale facilities.

Biomedical and Environmental Research (HA 02)

A broad effort is being undertaken at ORNL to gain an understanding of the interaction of energy-related pollutants with living organisms, and to understand their transport, transformation, and ultimate fate in the environment. This effort is funded by the DOE Office of Energy Research, Office of Health and Environmental Research. This information is being used in ongoing DOE activities to insure that they are conducted safely and effectively and that potential hazards to humans and ecological systems are identified, evaluated, and anticipated. One example is the work being carried out in support of coal conversion technologies which is coordinated by the Life Sciences Synthetic Fuels Program (LSSFP). The LSSFP serves as the focal point where information developed in the life sciences research programs is integrated with technology-specific information to assist in development and assessment of coal liquefaction and gasification technologies.

The major life sciences research programs involve (a) biological studies of carcinogenic, mutagenic, and toxicologic effects of physical and chemical agents associated with energy production, (b) ecological studies of the effects of energy technologies and transport of contaminants from these technologies on and through particular ecosystems and assessments of the present and future effects of energy-related pollutants on the environment, and (c) studies of the physics and chemistry

of problems related to the adverse effects, transport and chemical evolution, and the quantitative measurement of such pollutants.

Biological studies include investigations of systems damaged from ionizing radiation, and chemical agents including the organic and metallic constituents of coal tars and heavy metals associated with energy production. Results of these investigations will be used in estimating risks to workers in the energy industry, to other human populations, and to ecological systems subject to exposure to materials released to the environment as a consequence of existing and developing processes for the production of energy.

Major research efforts are involved with developing biological and ecological test systems for toxicity hazards analyses. Investigations designed to elucidate transport and transformation processes provide data concerning the fate of effluent components in the environment. Such data are used in determining and quantifying parameters for critical pathways to man and his environment which, in turn, are important to risk analyses.

Physical and technological programs include studies that are relevant to problems in atmospheric chemistry and physics, to the transport and ultimate fate of energy-related pollutants in the atmosphere, to radiation chemistry, and to the development of new principles for advanced analytical instrumentation. Significant efforts are being devoted to the new laser techniques for pollutant detection and characterization, to studies of ion chemistry and photochemistry of pollutant and atmospheric species, and to studies of surface phenomena involved in particle accretion and surface adsorption in atmospheric particulates.

Understanding the global carbon cycle, man's influence on this cycle, and the ecological consequences of elevated atmospheric $CO_2$ and climate change requires a broadly based program of research. Key issues include the role of terrestrial vegetation in the global carbon cycle, the influence of increased $CO_2$ concentrations in the atmosphere on climate as interpreted by past bioclimatic records, effects of elevated $CO_2$ on ecosystems, improved global carbon cycle models, and reservoirs and cycling of carbon in aquatic systems.

Acid deposition is also of programmatic interest to ORNL. We continue to develop our research program in the biological effects and assessment areas as regards acid deposition.

## Life Sciences Research and Biomedical Applications (HB)

The DOE Office of Health and Enviromental Research is funding research at ORNL which is providing a foundation for achieving a more thorough understanding of the mechanisms responsible for the biologic damage caused by various chemical and physical agents associated with energy production and a potential means for generalizing from specific results. Insight into the ways in which biological damage is or can be repaired is provided in some cases. The research is making available information

that can be used in developing sensitive and reproducible assays of the biologic damage caused by energy products, thus increasing our ability to measure that damage. The Laboratory is continuing to maintain a strong, fundamental physics research program. New scientific knowledge is being sought of both the structure and properties of matter in all phases and also the mechanisms that play important roles in the interactions of pollutants in the biosphere.

The mechanisms by which mutagenic agents (chemicals and radiation) cause damage to genetic material are being investigated. It is expected that knowledge of these fundamental mechanisms gained by studying model systems in microorganisms and animals will facilitate understanding of similar events in man and strengthen the scientific bases for extrapolations made from animal to human systems.

The replication of DNA (the information repository of the cell), the transfer of information which directs the manufacture of cell components, and the mechanisms by which this information is used to regulate and control cell events and function are being investigated. Moreover, the nature of the damage to DNA produced by chemicals and radiation and the mechanisms and extent of repair of this damage are being studied. Knowledge of these processes contributes to a more thorough understanding of the molecular events that occur during the transformation of cells by carcinogens and during the production of damage to cells by toxic agents (e.g., products of fossil fuel and nuclear energy technologies). Such understanding will lead to establishment of broader concepts of health effects that can be more easily generalized to a wide variety of noxious agents and can be more confidently extrapolated to effects on man.

Other projects are concerned with defining the mechanisms that control the active transport of biologically important materials between cells and their environments, the regulation of various physiologic processes, the three-dimensional structure of biologically active molecules, the use of bioprocesses for energy production, waste treatment or resource recovery, and the synthesis of structurally modified organic compounds needed for various investigations of mutagenesis and carcinogenesis.

The physics research program consists primarily of basic studies of the fundamental properties of matter in all phases (gas, liquid, and solid) which are directed toward providing information on topics such as the structure and properties of materials of biological importance, the physical processes that are important in the transport of pollutants through the atmosphere, and the interactions of pollutants with biological materials. Extensive application is being made of recently developed high power tunable lasers. The scope of work includes unique applications of optical techniques to basic atomic and molecular physics studies and solid state and surface physics studies, and to investigations of fast chemical reaction rates. Research areas which will continue to receive emphasis include the electronic structure of submicron objects (particulates, aerosols, fibers, holes, etc.), optical and electronic properties of solids and biological macromolecules, and the interaction of radiation (photons, electrons, nucleons, and heavy-charged particles) with condensed matter.

The Nuclear Medicine Applications Program consists of integrated tasks which function in response to the role of the Department of Energy in promoting the beneficial applications of nuclear technology. Principal areas of interest include new radiopharmaceuticals for diagnostic in vivo procedures, which include agents for adrenal, myocardial, and brain applications. Major emphasis is presently focused on investigating the properties of a unique class of radiolabeled long-chain fatty acids that have been found to be "trapped" in the myocardium. Other areas of interest include the development and evaluation of radiolabeled organometallic compounds for cancer therapeutic research. The research and development projects are complemented by active extramural collaborative efforts through the Medical Cooperative Programs. Such collaboration provides clinical evaluation and establishes ties with expertise in the fields of cardiology, rheumatology, and oncology.

## MAJOR INITIATIVES

Increased emphasis at ORNL is being given to tasks that are:

- o assessing the effects of acid deposition on agricultural and natural soil systems;
- o assessing the potential environmental and health impacts of major fossil energy technologies;
- o investigating global biogeochemical cycles and carbon dioxide;
- o investigating biotechnologies for waste treatment, resource recovery, and fuel production;
- o developing a risk analysis program;
- o expanding our capabilities in toxicology;
- o developing new techniques for pollutant measurement and monitoring; and
- o contributing to radiation protection.

These important new and expanding areas of work are explained in the following.

Acid Deposition from the Atmosphere. Acid deposition is rapidly becoming one of the major environmental issues of the decade. The occurrence of acid rain and its potential effects on terrestrial and aquatic ecosystems in Sweden was brought before the United Nations in 1968, and since then innumerable research projects on the subject have developed in Scandinavia, Northern Europe, the United States, and Canada. With few notable exceptions, early reviews and research plans on the "acid rain problem" took the attitude that effects on the environment would be detrimental. While potential for such detrimental effects exists, some beneficial effects may also result from the accelerated deposition of essential nutrients associated with acid rain. Acid rain research at Oak Ridge National Laboratory is predicated upon the philosophy that

this important environmental issue must be approached with scientific objectivity to form the bases of national effects and assessments studies and subsequent policy decisions.

The major contributors to acid deposition are sulfuric and nitric acid, which are formed as a result of atmospheric loading of $SO_x$ and $NO_x$ emissions from both stationary and mobile sources. Changing energy use patterns, advanced fossil energy technologies, improved environmental control technology, and revised air quality standards are all potential factors determining future patterns of acid deposition.

Current research efforts at ORNL dealing with atmospheric acid deposition represent a broad-based interdisciplinary approach to understanding the scientific issues associated with assessment of the long-range consequences of acidic deposition. ORNL research in the area of atmospheric chemistry and deposition has served a leading role in understanding the importance of the dry particulate component of atmospheric deposition in the cycling of elements in terrestrial ecosystems. In addition, innovative techniques developed at ORNL have led to advanced knowledge of the role of forest canopy structure in scavenging of pollutants from an air mass. The ecological consequences of acidic deposition have been a major focal point of ORNL programs dealing with air pollution-related impacts of energy technologies. ORNL research on vegetation effects of acid rain has served as a model for methodology development in the simulation of rainfall for effects research.

ORNL scientists were the first to explore the potential for interactive effects of acid precipitation and gaseous pollutants of regional importance such as ozone and sulfur dioxide, and new initiatives currently underway will expand this effort to full-scale studies of crops under field conditions.

Research on ORNL's Walker Branch Watershed (WBW) represents the second longest continuous study of the role of precipitation chemistry in forest nutrient cycling in the United States. From its beginnings during the International Biological Program, WBW has produced detailed analyses of the cycles of nitrogen, sulfur, and certain heavy metals in the forest ecosystem. Current research on WBW includes new intitiatives to quantify the importance of soil sulfate adsorption to soil nutrient depletion, and characterization of organic sulfur pools on the watershed. A major product of soils-related research at ORNL has been the capability to predict the sensitivity of soils to acid deposition effects, both from nutrient depletion, and perhaps more importantly as a source of inputs of acid to surface waters sensitive to impacts on aquatic life forms.

Coal Conversion. A major effort in the life sciences program is directed at supporting the development of environmentally acceptable synthetic fuel technologies. This activity is being coordinated and focused through the Life Sciences Synthetic Fuels Program (LSSFP) to ensure that the broad, multi-disciplinary resources of the life sciences program are efficiently and effectively applied to supporting these technologies. The LSSFP consists of two major components: the "core" research program and technology-specific assessment projects.

The core research program is aimed at developing the basic information needed to understand and evaluate the potential environmental, health and safety impacts of liquefaction and gasification technologies. Activities involved include, for example: developing and validating test systems for use in evaluating the toxicity of coal conversion related materials; tracing the transport, transformation, and fate of pollutants emitted to the environment by these technologies; and developing new methods of detecting and monitoring for materials produced during coal conversion. These research programs are conducted by the appropriate Laboratory divisions with LSSFP serving a general coordinating role.

Technology-specific assessments for direct coal liquefaction and coal gasification are currently being developed through studies of the H-Coal pilot plant and of the low Btu gasifier installation at the University of Minnesota-Duluth (UMD). These assessment activities initially involve developing a data base of operating, health, and environmental information for the respective technologies through the conduct of on-site characterization and monitoring programs. Information developed through these characterization activities is then evaluated by multidisciplinary teams operating with benefit of the knowledge and techniques gained through the core research program. This information is then used as the basis for assessing the potential environmental, health, and safety impacts of the subject technology.

While the H-Coal and UMD assessments activities are still on-going and have yet to be completed, important information has already been developed and is being applied to supporting coal conversion technology development. For example, information developed at UMD indicated the importance of industrial hygiene consideration at low Btu gasifiers, particularly during start-up of the facility. This knowledge and related capabilities developed during the UMD program were instrumental in the ability of ORNL to provide requested industrial hygiene support to the DOE fossil energy program during start-up of the CAN-DO gasifiers. In another instance information developed in the research programs indicated that hydrotreating might be very effective in reducing the toxic potential of coal liquids. Further work is in progress to more fully evaluate the utility of this approach to reducing the potential hazard of some products produced by coal conversion technologies.

In addition to the on-going H-Coal (direct liquefaction) and UMD (gasification) evaluations, two other areas are being considered for future activities: the production of liquid fuels through indirect coal liquefaction and the processing of eastern shales to recover oil and other by-products. Each offers a potentially large contribution to the production of synthetic liquid fuels. Determining the potential environmental and health impacts of these technologies will be an important aspect in the successful development of industries based on these concepts.

Biogeochemical Cycles and Carbon Dioxide. Recognition that increases in the concentration of $CO_2$ in the atmosphere due to fossil fuel combustion may lead to significant modification of the earth's climate has led to intense efforts by the world scientific community to understand the dynamics of the global carbon cycle. Building on a strong history in the study of global biogeochemical cycles, ORNL is involved in major research programs to refine our understanding of the global carbon cycle, its dependence on climate, and its relationship to other chemical cycles such as nitrogen and sulfur.

Carbon cycle research at ORNL emphasizes the role of terrestrial ecosystems. Recently, improved estimates of the present-day storage of carbon in vegetation and soil have been prepared. These are based on computerized maps of the distribution of types of terrestrial ecosystems. Using these data, ORNL investigators have developed mathematical models for the terrestrial carbon system which are used for analyzing changes in the carbon cycle in the recent past as well as for projecting future responses.

The degree to which the release of $CO_2$ by forest clearing activities may also contribute to rising atmospheric levels remains controversial. ORNL scientists have contributed detailed summaries of the changes in terrestrial carbon storage and associated releases to the atmosphere for regions where they have particular expertise, the eastern United States and Malaysia.

Studies of the terrestrial component of the global carbon cycle are continually analyzed in a total carbon cycle context. In particular, scientists at ORNL have developed models for the turnover of carbon in the world ocean. In a recent study various alternative approaches to modeling the ocean reservoir were compared with attention to the implication of assumptions about the ocean for complementary historical exchanges of carbon between the atmosphere and terrestrial ecosystems.

Projections of carbon cycle response to future climate change are based in large part on studies of past climates and carbon dynamics reconstructed from proxy data such as tree-ring increments or pollen abundances. ORNL staff are engaged in the research as part of the Laboratory's overall carbon cycle programs.

ORNL carbon cycle studies are moving toward greater emphasis on the influence of climate on the dynamics of the cycle. At the same time, data summaries and models are being refined to reflect added spatial detail. Models are under development which explicitly treat the dependence of the distribution of terrestrial vegetation and associated carbon storage on climate. These models will have a spatial resolution of $5^{o}$ in latitude or longitude.

Several new $CO_2$-climate initiatives are being pursued. ORNL investigators are developing methods for sensitivity analysis of general circulation models of the atmosphere used to assess the climate change likely to arise from increases in $CO_2$. ORNL staff are also pursuing studies of carbon in freshwater ecosystems. One effort is focused on assessment of

the transport of terrestrial carbon to the ocean by the world's rivers. The second is analyzing the role of reservoirs in the carbon cycle and changes in reservoir management implied by a $CO_2$-induced climate change.

Biotechnology Development. Biological processes offer great promise for both near-and long-term production of fuels and chemical industry feed materials, as well as for the abatement of pollution and the recovery of valuable resources. Biological systems can also be valuable tools in the production of materials for the biomedical sciences. Innovative approaches are needed for monitoring and measuring bioprocess intermediates and products and other fluid constituents that are important in the biomedical and environmental areas.

ORNL possesses the expertise in process engineering R&D and in the biological and environmental sciences to contribute significantly toward (1) the development of efficient bioprocesses for fuel production from biomass, (2) the development of efficient waste treatment techniques, especially for those wastes associated with energy production, (3) the recovery of valuable resources such as fuels and metals, and (4) the development of advanced concepts for measuring biologically important constituents in complex mixtures.

Four major areas of concentration are envisioned under this initiative. The first of these, bioengineering research, would involve investigation of advanced bioreactor concepts, high-resolution separation techniques for biological materials, and immobilization of active biological agents.

The second area of concentration, applied biological and chemical research, would involve reaction kinetics and other areas lending support to the development of specific processes.

The third major area of concentration, advanced instrumentation, would focus on the development of instrumentation either to measure and monitor important parameters in bioprocesses or to measure environmental and human exposure to energy pollutants.

Bioprocess development will be the fourth major area of concentration. In this area, the potential usefulness of various bioprocesses in environmental control technology, biomass use, and resource recovery would be investigated. This effort would involve determining the most efficient biological agents and the optional conditions for a given biological process. Fuels, such as methane or alcohols, and other chemicals that can be derived from waste materials or biomass would be emphasized, and environmental control technology useful in energy production would have priority.

Risk Analysis. Site-specific, regional, and generic assessments of energy technologies and assessments of generic issues have been performed by ORNL and others. Many of these assessments stopped at estimation of exposure and did not proceed to a risk assessment. The

Laboratory has now organized a risk analysis activity to develop and apply comprehensive principles of risk assessment, and to provide a basis for broad scientific and political acceptance of risk concepts. In concert with these on-going activities in risk assessment, ORNL is implementing a Risk Assessment Information Center. The Center is providing data evaluation and analysis, computer and software support, and information transfer. The Risk Assessment Information Center is currently carrying out risk information activities in three areas: (1) collecting and indexing articles on risk assessment methodologies; (2) compiling an automated locator file of information resources such as subject experts and collections of data; and (3) compiling and automating data on health effects related to risk assessment. Information staff serve as members of the risk assessment teams and as such compile, document, and evaluate data used in the risk assessments.

Since a risk-free state of life does not exist, it is clear that practical issues such as risk apportionment, comparative risks, risk-benefit tradeoffs, and effective input to policymaking must be addressed. To date no energy technology has been totally rejected because it was too risky. Rather, it has been a case that energy policymaking has been dominated by political decisions that are often inconsistent combinations of readiness, economic factors, technological feasibility, perceived risks, and actuarial estimations of risks. Energy crises can and have overridden all other considerations. A concerted effort on risk assessment, accompanying technology development, will be necessary if we are to surmount some of the political and perceptual problems related to energy technologies and to ensure that the best scientific documentation is available for unanimous input to energy policymaking.

Toxicology. Experimental data on acute, subchronic, and chronic toxicity of new synthetic fuels and the byproducts of their production are urgently needed to provide a basis for assessing the health risks to individuals who may be exposed when these new energy systems are developed and put into full-scale use.

Confirmation and extension of initial results on acute toxicity from exposure to such materials are needed. More importantly, however, data on subchronic and chronic toxicity caused by long-term, low-level exposure are almost nonexistent, and this gap must be filled.

ORNL has already initiated a program to study the acute and subacute toxicity of energy-related materials and other environmental pollutants and has added a small team of toxicologists and pathologists to the existing support staff of chemists, biologists, and physiologists. Moreover, some of the needed facilities are available, particularly the disease-free quarters that are required for subchronic and chronic toxicity experimentation. The Laboratory has extensive experience in carrying out long-term animal experiments with hazardous chemical substances in which protection is provided to ensure the integrity of the experiment, the health of the workers, and the protection of the environment within and around the Laboratory.

In this program, materials obtained from various developing energy processes will be examined initially for acute toxic effects, using standard protocols. Selected materials will then be investigated more extensively for subchronic or chronic toxicity caused by long-term exposure at various exposure levels. Damage at both the point of entry into the body and in organ systems will be characterized to determine the kind and severity of disease produced, the part of the body affected, and the comparative responses of several animal species. For selected representative test materials, the uptake and fate of the substances in the body will be determined to relate the doses delivered by different routes of exposure to the adverse health effects. For the most important compounds, the mechanisms by which the materials produce their toxic effects will be investigated. The combined data on toxicokinetics, pathology, and mechanisms ultimately will be the basis of the health risk assessment.

Development of New Techniques for Pollutant Measurement. There is a crucial need to identify and monitor a spectrum of pollutants associated with a variety of new energy technologies. The requirement for these techniques exists in both the workplace as well as in the environment. A principal goal has been to devise new techniques and improved monitors for detecting pollutants from coal conversion processes. New instruments are needed to warn workers of elevated pollutant concentrations, monitor levels of pollutant exposure, and demonstrate compliance with Federal standards limiting PNA concentrations in the work environment. Skin contamination is a major industrial hygiene concern and the hand-held lightpipe luminoscope has been developed to detect this contamination in a safe and efficient manner. A derivative ultraviolet absorption spectrometer (DUVAS) has been developed to characterize and monitor aromatic vapor levels. These instruments are now being field-tested at actual synthetic fuel facilities. The IR-100 Award from Industrial Research and Development Magazine was given to the Oak Ridge National Laboratory for the portable spill spotter which is used to detect coal conversion pollutants on surfaces. Synchronous luminescence and room temperature phosphorescence techniques are being developed as rapid-screening analysis tools and possible application as a passive monitoring badge for PNA vapors.

Over the past three years major growth has occurred in the development of broad-based laser related research with application for single-atom detection. In addition to the program in resonance ionization spectroscopy in gases, new efforts include laser spectroscopic analysis of materials from solid surfaces, multiphoton ionization spectroscopic studies of organic, atmospheric, and pollutant molecules, laser photoelectron spectroscopy of molecules, and combinations of laser multiphoton and mass spectroscopy of molecules and of isotopically selected atoms. It can be anticipated that this research program will have a major impact on pollutant characterization and detection methodologies in the future. It will not only help to insure an ability to monitor compliance with regulatory standards for pollutant emissions, etc., but it will also bring new tools to bear on scientific questions concerning the transport, chemical evolution, and ultimate fate of energy-related chemical species.

Contributions to Radiation Protection. The Laboratory has long been involved in the development of radiation protection guidance. ORNL staff are interpreting the new primary radiation protection guidance of the International Commission on Radiation Protection (ICRP). This interpretation involves development of secondary limits for radionuclides in the form of annual limits of intake and derived air concentrations for workers. Development of the secondary limits represents a large, computational effort involving data describing the energies and intensities of the various radiations emitted by the radionuclide, the deposition and retention of material in the body, and the estimation of dose in sensitive target tissues of the body. The resultant secondary limits are being published in ICRP Publication 30. The first two parts of this three-part publication have been issued and contain data for 433 radionuclides; Part 3 contains an additional 321 radionuclides. Details at various stages in the computations are issued as supplements to Publication 30.

This effort represents the first systematic revision in radiation protection guidance since 1959. It is interesting to note that the new secondary limits supersede values computed twenty years ago at ORNL. Both the previous and the updated limits apply to occupational exposure of adults. In order to extend the effort to include population groups, work is now in progress to provide the dosimetry limits for children of various ages.

## RECENT MAJOR ACCOMPLISHMENTS

The major accomplishments in the biomedical and environmental sciences program can be defined in relation to the programs of which they are part. Some accomplishments from the recent past are:

### Nuclear Programs

- o New secondary radiation protection limits issued by International Commission on Radiological Protection (ICRP Publication 30) for about 750 radionuclides have been produced and a computer searchable data base created for primary metabolic and dosimetric data used to update ICRP Publication 30.

- o Continental-scale (U.S., Canada, and Mexico) radiological assessment of exposures due to radon daughters.

- o Discovery that soil absorption of strontium-90 can be increased three orders of magnitude by soil conditioning with alkali metal hydroxides.

- o Soil to plant transfers for technetium-99 near two gaseous diffusion plants was found to be one to two orders of magnitude less than published transfers measured using potted soils contaminated with pertechnetate ($^{99}TcO_4$).

### Life Sciences Synthetic Fuels Program

- o Mutagenesis, carcinogenesis, toxicity, and teratogenesis criteria for relative biological hazards of low Btu gasification and coal liquefaction materials.

- o Short-term mutagenesis assays of products, effluents, and wastes from shale oil, coal liquefaction, and coal gasification processes.

- o Environmental assay for embryo toxicity and teratogenicity (Science cover).

- o Initial models for transport and fate of polycyclic aromatic hydrocarbons in aquatic environments.

- o Mitigating strategies such as hydrotreating offer the potential to reduce toxicity of products and effluents.

- o Mobile process development unit designed and fabricated for advanced wastewater treatment facilities.

Life Sciences Instrumentation

- o Derivative Ultra Violet Absorption Spectroscopy (DUVAS) tested at the University of Minnesota-Duluth gasifier and the H-Coal facility at Catlettsburg, Kentucky.

- o Lightpipe luminoscope for detecting skin contamination by oil and tar developed.

- o IR-100 Award for portable spill spotter for detecting organic pollutants on surfaces developed.

- o Technology transfer conference for potential manufacturers and users of instruments for environmental monitoring held at ORNL.

Biotechnology

- o Award for bioanalytical instrumentation (E. O. Lawrence Award to C. D. Scott).

- o Simultaneous production of hydrogen and oxygen from plant chloroplasts — ferredoxin-hydrogenase system.

Health Effects Research

- o First electron microscopy techniques for nucleosomes from cells with true nuclei (eukaryotes) developed.

- o Techniques for maintenance of frozen embryos and vital organs, such as pancreas, in a vital state.

- o Method to inhibit fibroblast development in vitro was developed resulting in ability to produce pure epithelial cell lines as research tools. This method is especially valuable because most human cancers are of epithelial origin.

- o Repair of premutational spermatogonial damage in fertilized eggs of mice demonstrated.

- Ethylnitrosourea — a supermutagen in mice — was demonstrated to be more damaging in spermatogonial stem cells than in meiotic or postmeiotic stages of both sexes. This supermutagen provides a method to produce many kinds of mutants as needed.

These and other accomplishments in the biomedical and environmental programs have led to many awards. The Industrial Research-100 Award is especially significant because for this award innovations are judged for importance, uniqueness, and usefulness with the view of bringing better products into the market for consumers. Recent Industrial Research-100 Awards in the biomedical and environmental programs are:

IR-100 Awards of 1977

- Nitrate Recycle and Disposal Process for Removal of Nitrogen-Containing Contaminants from Industrial Waste Streams
- Portable Centrifugal Fast Analyzer for Medical Diagnostic Tests and Environmental Monitoring
- One Atom Detection Using Resonance Ionization Spectroscopy
- Cytriage Automatic Blood Cell Separator

IR-100 Awards of 1978

- Pressurized Continuous Annular Chromatography
- Ultrasound Skin Burn Analyzer

IR-100 Award of 1979

- Tapered Fluidized Bed Bioreactor

IR-100 Award of 1980

- Portable Fluorescence Spotter

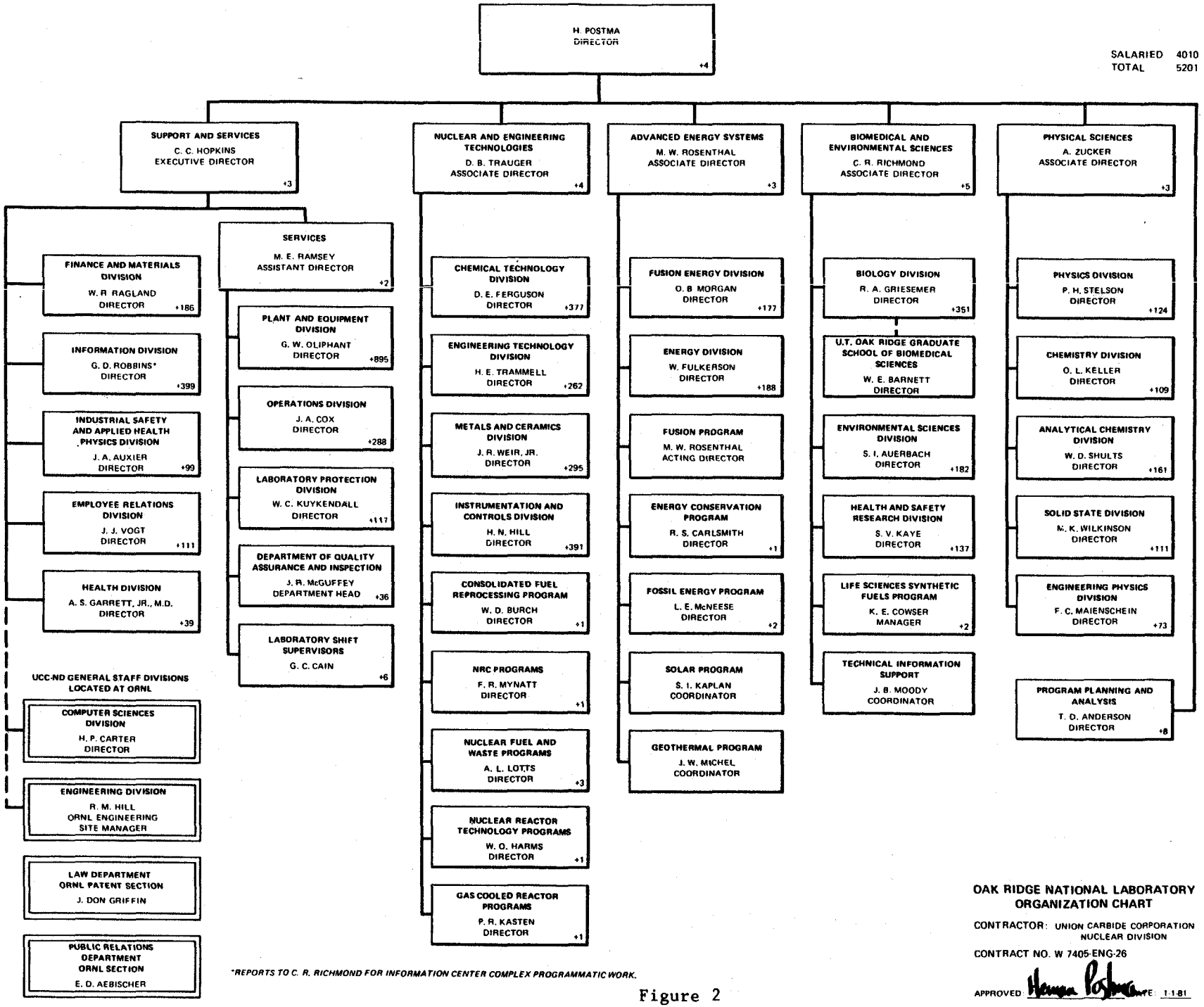
ORNL staff published 690 articles in journals, books, and reports in the subject area of biomedical and environmental sciences during 1980. These included 529 articles in journals and books and 161 reports. There were several publications not included in this tabulation; for instance, theses, book reviews, abstracts published in journals or symposia proceedings, pending publications and reports such as monthly and bimonthly progress reports, contractor reports, and reports for internal distribution.

A summary of the biomedical and environmental sciences publications in 1980 shows the totals by division and by publication type.

| Division | Journals | Books/ Book Chapters | Reports | Totals |
|---|---|---|---|---|
| Analytical Chemistry | 7 | 4 | - | 11 |
| Biology | 130 | 49 | 3 | 182 |
| Chemical Technology | 9 | 5 | - | 14 |
| Information R&D | 2 | 5 | 33 | 40 |
| Health & Safety Research | 107 | 57 | 72 | 236 |
| Energy | - | 1 | - | 1 |
| Environmental Sciences | 89 | 57 | 53 | 199 |
| Computer Sciences | 6 | 1 | - | 7 |
| TOTALS | 350 | 179 | 161 | 69 |

## ORGANIZATION

The Laboratory is organized along functional and programmatic lines into a decentralized matrix organization. Figure 2 gives an organization chart of ORNL. The Associate Laboratory Director for Biomedical and Environmental Sciences has recently been given responsibility for directing the health, safety, and environmental affairs of the Nuclear Division of Union Carbide Corporation (UCC-ND), of which ORNL is a part. In addition to the evident advantages to UCC-ND, this responsibility gives the Associate Director a broad perspective on health, environment, and safety in industry. Figure 3 shows the organizational structure of biomedical and environmental research at ORNL. The functional relationship involves the Biology, Health and Safety Research, and Environmental Sciences Divisions which report to the Associate Director for Biomedical and Environmental Sciences. The information center component of the Information Division, the Information Center Complex, is primarily focused in the biomedical and environmental areas and also reports to the Associate Director. The Associate Director is kept apprised of the life sciences components of all of the Laboratory's programs by the respective division directors; in addition, the life sciences synthetic fuels work is combined into a program which reports to the Associate Director in a functional relationship. The life sciences research in each of these divisions or programs will be discussed in greater detail in the following sections of this report.




*REPORTS TO C. R. RICHMOND FOR INFORMATION CENTER COMPLEX PROGRAMMATIC WORK.

Figure 2

**OAK RIDGE NATIONAL LABORATORY ORGANIZATION CHART**

CONTRACTOR: UNION CARBIDE CORPORATION NUCLEAR DIVISION

CONTRACT NO. W 7405-ENG-26

APPROVED: Herman Postma DATE: 1-1-81

JUNE 1981

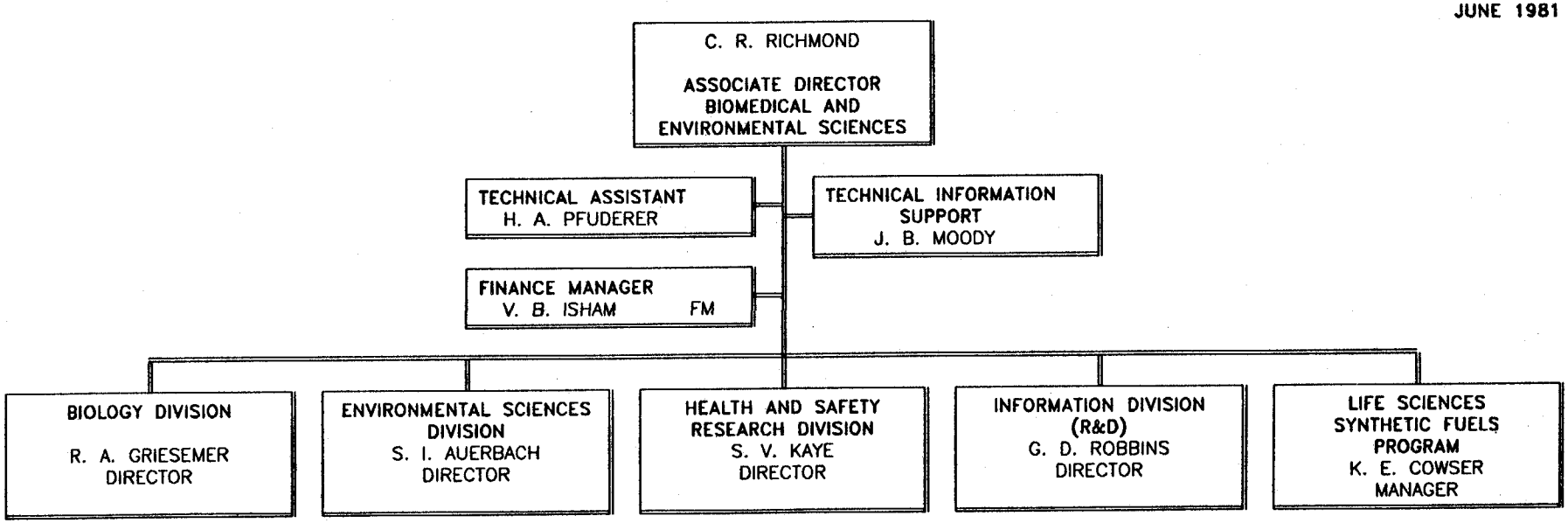



Figure 3

# BIOLOGY DIVISION

## INTRODUCTION

A major objective throughout the history of the Biology Division has been to develop a scientific foundation for evaluating the health effects of new and changing technologies. At first major emphasis was placed on the investigation of health effects of ionizing radiation, both genetic and somatic, during the emergence of technologies related to atomic energy. More recently the area of interest has been broadened to include investigation of various chemicals and complex substances produced by a variety of energy technologies, especially that of fossil fuel.

The strategy has been to use a few whole animal models to obtain data that may be most directly applicable to human risk models and to underpin that work with studies on lower organisms and cell systems, and with investigations of fundamental mechanisms at the cellular and molecular levels. This combination has provided answers to pressing problems of immediate concern while at the same time keeping the mission-oriented research in constant contact with its scientific roots. Thus developments in fundamental science serve as a source of new knowledge upon which the success of future applied work depends; and, in addition, the nucleus of scientific expertise is regularly called upon by those working on applied programs for help in solving their problems. The interaction also works in the reverse direction by making investigators in fundamental science aware of the practical problems and the ways in which their science relates to those problems.

A review of recent accomplishments of Biology Division staff can serve to show the strengths of the research programs. Major accomplishments are:

- Method to inhibit fibroblast development in vitro was developed resulting in ability to produce pure epithelial cell lines as research tools. This method is especially valuable because most human cancers are of epithelial origin.

- Repair of premutational spermatogonial damage in fertilized eggs of mice demonstrated.

- Found that offspring which inherited "major histocompatibility complex (MHC)" from short-lived strain of mice had a lower life expectancy than the offspring which inherited the MHC of the long-lived strain.

- Demonstrated that ethylene oxide, a chemical used widely in industry and in hospitals for destroying harmful microorganisms, causes damage to mouse chromosomes.

- Developed fast, simple, and sensitive test for teratogens.

- Found that multiple exposures of the lung to cadmium aerosol or $NO_2$ result in adaptation to these materials by an as yet unknown mechanism.

- Found that sequential exposure of lungs to multiple agents produces lesions that are distinct from those that occur after a single agent.

- Radiation carcinogenesis studies with neutrons have shown that the assumption of linearity for dose-response relationships is not valid.

- Identified a cell surface protein in mouse lung tumors that is not present in normal lungs nor in other tumor types. Using the unique protein it may be possible to develop a method for producing antibodies specific to tumor cells.

- Mutagenesis, carcinogenesis, toxicity, and teratogenesis criteria for relative biological hazards of low Btu gasification and coal liquefaction materials.

- Short-term mutagenesis assays of products, effluents, and wastes from shale oil, coal liquefaction, and coal gasification processes.

- Developed new affinity labels to examine the enzyme that catalyzes photosynthetic reduction of atmospheric $CO_2$ to yield carbohydrates.

- Pfizer Award to Fred Hartman for enzyme structure research (affinity labeling technique).

- Dr. James Regan was elected a Fellow of the Japanese Society for the Promotion of Science. He was presented with the medal of the National Cancer Institute of Japan and the medal of Tokai University for his work on DNA repair mechanisms.

## ORGANIZATION

As Figure 4 shows, the Biology Division is organized into four sections and two programs. The sections are:

- Molecular and Cellular Sciences
- Cancer and Toxicology
- Cellular and Comparative Mutagenesis
- Mammalian Genetics and Teratology

The research in each of the sections will be briefly outlined.

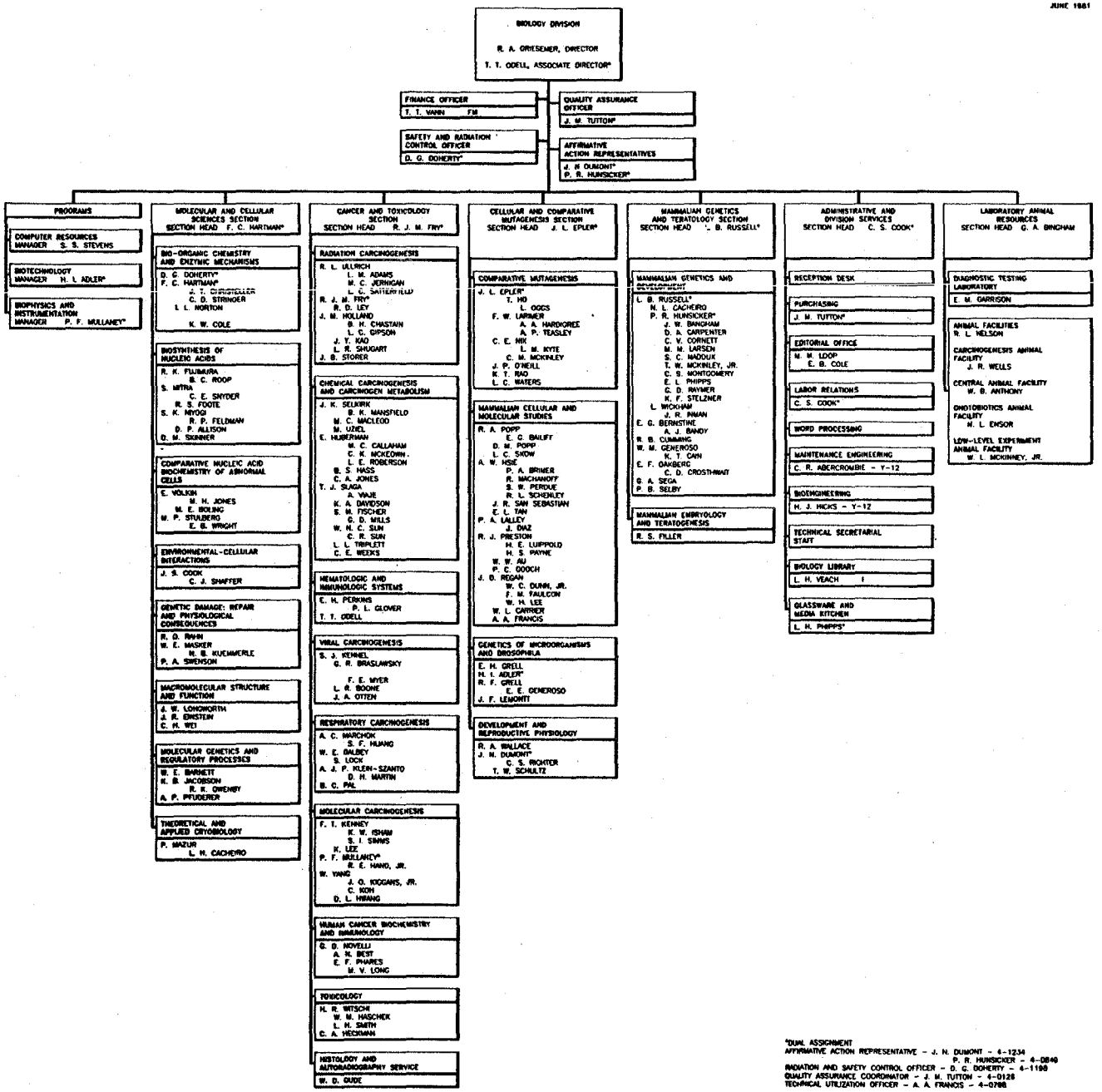

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Figure 4

Molecular and Cellular Sciences

With the early realization that an understanding of genetic and somatic effects of human exposure to radiation would require a knowledge of gene structure at the molecular level, strong programs in nucleic acid chemistry and biochemistry were established in the Biology Division. Simultaneously, molecular radiation biology flourished especially with respect to recognition and characterization of processes by which DNA — damaged by irradiation — could be repaired *in vivo*.

Other areas that grew naturally because of a major emphasis on genetics were protein synthesis (the final product of gene expression), enzymology (regulation of enzyme action controls gene expression which in turn is linked to carcinogenic and mutagenic events), and developmental biology (an area that can provide valuable insights into regulation of gene expression).

Although the missions have been broadened to include adverse health effects of chemicals (especially those related to coal products) and viruses, it is recognized that, as with radiation, the more profound consequences of exposure in these insults result from their interaction with the cellular genome.

Many of the fundamental studies are closely integrated with mission projects through formal collaborations between senior investigators. Some specific problems being tackled jointly by members of applied and basic groups include mechanisms of cell transformation by viruses, characterization of DNA-carcinogen adducts formed *in vivo*, and influence of carcinogens on *in vitro* transcription of chromatin.

Current emphasis remains on nucleic acids. Included are a molecular biology — i.e., replication and transcription of DNA and their regulation, repair processes, molecular genetics, and structure/function relations in DNA and chromatin. These fields are clearly directed toward acquiring a more comprehensive understanding of carcinogenesis and mutagenesis. Also represented are developmental biology, cryobiology, enzymology, protein chemistry, protein biosynthesis, membrane biology, and x-ray diffraction.

Cancer and Toxicology Section

The objectives of the section are:

(1) to determine the mechanisms by which chemical, radiation, and viral agents cause biological effects, in particular, cancer;

(2) to develop molecular, cellular, tissue and animal test or model systems for various types of investigation but, in particular, for the assessment of the hazards of exposure to toxic, mutagenic and carcinogenic agents; and

(3) to provide the best possible information, using state-of-the-art techniques, to the DOE and other agencies about the noxious effects of the agents entering the general and working environment.

The assessment of the biological effects must involve chemical analysis, and determination of toxic, mutagenic, teratogenic and carcinogenic effects. Appropriate assay or test systems are being developed while the longer term but ultimately more valuable studies on mechanisms are also underway. The research on carcinogenesis and toxicology can be subdivided as follows: (1) chemical carcinogenesis; (2) respiratory carcinogenesies; (3) radiation carcinogenesis; (4) viral carcinogenesis; (5) molecular carcinogenesis; (6) cancer immunology; (7) toxicology; and (8) biological processing.

Cellular and Comparative Mutagenesis

Experiments with lower organisms provide relatively rapid and cheap means for mutagenicity testing of large numbers of chemicals. The applicability of some of these test results to whole-mammal mutagenesis must subsequently be determined in order to make risk estimates for man.

A major program employs established tests on bacteria (Ames test), yeast, Drosophila (fruit fly) and mammalian cells in vitro to investigate compounds and mixtures generated by fossil-fuel technology for mutagenic action. The comparative approach used in this program provides a better indicator of potential hazard than the use of one system alone. The testing is closely coordinated with chemical analysis of the same materials carried out by the Analytical Chemistry Division. Some of the materials found to be positive in these systems are then investigated further for mutagenesis in whole mammals. There is also close cooperation with direct testing of these same materials for carcinogenesis. This program will continue to test materials of interest as they become available.

The use of the lower-organism systems for mutagenesis testing is based on the belief that the results are pertinent to the preliminary identification of human risks — a belief which is founded on the many similarities among the genetic mechanisms of all organisms. However, a number of disturbing unexplained differences have been found between the results with lower organisms and those with whole mammals. One approach to clarifying such problems is to obtain a better understanding of the basic mutagenic mechanisms involved in the various test systems. Another is to use mammalian test systems that more closely approximate the human situation. Both approaches have been and will continue to be used.

Work on mutagenic mechanisms in bacteria includes studies on the effects of mutagenic agents on DNA replication and repair, and of the role of these processes in mutation induction. Attempts are being made to determine the classes of mutagenic mechanisms and to assign mutagens to one or more such classes through knowledge of their chemical structure and their interactions with DNA and other cellular components. Specially permeabilized cells as well as normal cells are valuable tools for some of this work.

## Mammalian Genetics and Teratology

Experiments involving whole mammals provide the closest feasible approach to conditions that might exist when humans are exposed to possibly mutagenic agents. This is particularly true for chemicals, since the whole body possesses metabolic systems that can alter the introduced substance in such a way as to make it either more or less mutagenic, and mechanisms that can affect the transport of the substance or its metabolites to the target cells. The target cells studied in most of the whole-mammal mutagenesis projects are the germ cells, i.e., the focus is on effects on descendent generations or mutagenesis *per se*, rather than on mutagenesis as a possible indicator of carcinogenesis.

In addition to determining the frequencies of induced genetic lesions of various types, the whole-mammal work also concerns itself with the physical expression of the damage in the first-generation offspring. Among effects studied are interferences with male fertility (mostly due to certain chromosome abnormalities) and skeletal abnormalities (due to various genetic lesions throughout the genome).

A new area of emphasis has been opened by the discovery that the fertilized egg of some strains of mice can repair potentially mutational lesions introduced by sperm that had been earlier exposed to chemical mutagens. Strains that are repair-competent or repair-deficient for different classes of mutagens will be characterized and the genetics and biochemistry of these conditions explored. This has implications for practical as well as fundamental considerations, such as the need to find sensitive tester strains and the possible correlations between genetic repair deficiency and susceptibility to toxic effects or carcinogenesis. It will also shed light on the processes by which premutational lesions are converted into aberrations.

One area under growing investigation is the genetic and biochemical analysis of mutations recovered in specific-locus experiments. This serves not only to determine the nature of the basic genetic damage produced by different classes of mutagens, but also will reveal the fine structure of certain regions of the mammalian genome. The recent discovery of an extremely potent mutagen that produces a higher proportion of probably intragenic lesions than other mutagens should provide important material for these studies. Utilization of new cloning techniques will be very useful in the genetic fine-structure analysis.

Biochemical experiments are underway to provide molecular definition of proteins produced by normal allelic variants or by mutations induced in somatic and germinal cells. The next objective is to complement these studies by showing how specific structural alterations in nucleotide sequence of mouse hemoglobin genes affect the expression of these genes and to extend that information by defining how by-products of energy production alter nucleotide sequences at sites where mutations occur. The use of hemoglobin variants as indicators of somatic cell mutation provides a potential tool for monitoring mutation frequences in humans.

The mammalian effort has developed a rapid and sensitive in vivo prescreen for teratogenesis that is based on quantitative changes in the axial skeleton. By choosing a strain of mice that is developmentally labile for these characteristics and by determining the most sensitive developmental period for the shifts, effects of very small doses of teratogen can be detected rapidly.

Investigations on the initiation of abnormal developmental pathways are concentrating on various components of teratogenesis, namely, cell killing, altered differentiation potential, and maternal effects. Teratoma cell lines are being utilized for part of this study. Experiments are underway to determine whether the differences between inbred strains of mice with respect to sensitivity to polycyclic aromatic hydrocarbons are already expressed during the preimplantation period of development.

Biotechnology Program

Many anaerobic microorganisms produce significant quantities of organic materials useful as fuels in intermediates for organic synthesis. Methane, hydrogen, acetone, butanol, and ethanol are examples of these products. Recently developed techniques for producing oxygen-free conditions by the use of oxygen-consuming membranes derived from biological sources will allow researchers to propogate anaerobic microorganisms in pure cultures in the laboratory. Progress is being made on the physiological and genetic manipulation of anaerobic microorganisms in order to improve the yields of desired end products. Work in the Biology Division is directed toward removal of undesirable compounds from coal by the use of a community of microorganisms. Efficient cost-effective methods for the removal of organic sulfur are being developed. The techniques of DNA transformation are being used to allow the introduction of genes into Clostridium Butyricum, an anaerobic organism that makes butanol in significant amounts.

Biophysics Instrumentation Program

A new program has been established in the Biology Division which involves measurements on cells, chromosomes and other biological particles, searching for the rare events required to establish dose response relationships at low doses. A capability in flow cytometry and cell sorting is being established. These techniques permit the identification and physical separation of biological cells at rates of 10,000 per second. The high statistical accuracy which results from the high throughput makes this technique suitable for detection of rare events.

Many of the chemical compounds that are under investigation for mutagenic and carcinogenic effects are fluorescent as are their metabolic products. This property, in conjunction with the use of fluorochromes for DNA, enzyme substrates or fluorescent antibodies, is under evaluation as a probe for metabolic studies.

These studies also require high resolution (spectral and time resolved) measurements. The program is expected to expand into these areas as the biological endpoints become better defined.

# ENVIRONMENTAL SCIENCES DIVISION

## Introduction

The primary mission of the Environmental Sciences Division is to conduct research on the development, siting, and use of energy technologies in order to enhance environmental acceptability. Research programs are concerned with the principal nuclear and nonnuclear technologies and their associated fuel cycles. Program focus is on current methods of producing electrical power such as coal combustion and nuclear fission, as well as alternatives for the future energy technologies planned to provide a balanced and secure energy resource for the nation — coal conversion (liquefaction/gasification) processes, solar, hydroelectric, nuclear, and other advanced technologies.

Research on environmental transport of pollutants provides an understanding of how by-products of energy-producing technologies, as well as other pollutants, react when they are disposed of on land or are released to the atmosphere and surface waters. The quantity of these materials and their circulation pathways determine their availability to man and other organisms. Knowledge of material cycling in the environment is necessary to understand the effects of radiation exposure and chemical toxicity on organisms. An important research area is the determination of the effects on plant communities of sulfur oxide and other gaseous emissions from coal conversion technologies and fluoride releases from gaseous diffusion separation of nuclear fuels. Research associated with facility siting and power transmission corridors is directed to examining the effects of land use and habitat modification on wildlife composition and diversity in environments of the southeastern United States.

Diversity, stability, homogeneity, and productivity can be used as indices of ecosystem change in response to various impacts. The biological segment of an ecosystem integrates all environmental factors and is the most effective instrument for measuring environmental change. However, the capability to measure and evaluate ecosystem responses must be developed. Controlled experiments in greenhouses and growth chambers, interfaced with field research and long-term monitoring on available natural systems and new agricultural ecosystems, are producing a series of scalars to measure environmental effects of energy technology in a variety of terrestrial and aquatic ecosystems.

The primary objective of the Division's fundamental research programs is to understand more precisely and thereby quantify how biological and physical processes interact to regulate the transport, fate, and effects of materials in the atmosphere as well as the aquatic and terrestrial ecosystems. Techniques and models are being developed that may be applied to studying total ecological systems on local and regional scales.

The major programs of this type are biome and regional studies, ecosystem analysis, and experimental watershed studies. The goals of these programs are to describe the metabolism of natural and managed ecosystems, to develop a coherent ecological theory of the functional dynamics of these systems, and to assess the manner and extent to which integral landscape units respond to stresses of increasing human inputs.

The Division's assessment programs include not only the impact of varied energy technologies but also the application of ecological analysis to planned siting of facilities. Regional ecological studies encompass those research and assessment endeavors that span large geographical areas, ranging from several counties to sub-national regions.

The Department of Energy's (DOE) Oak Ridge Reservation has been recognized for many years as a significant, national, regional, and local resource for environmental research. Few sites have such varied natural resources, and none has comparable security and protection in a community containing so much scientific talent. The resources are typical of the southern Appalachian landscapes and represent ecosystems not extensively investigated by other research groups within this region. On June 5, 1980, 5500 ha of the site were designated by DOE as a National Environmental Research Park. Environmental research parks not only provide sites on which to conduct general research but also help environmental research programs (1) to develop methods for assessing and monitoring, both quantitatively and continuously, the environmental impacts of man's activities, (2) to develop methods for predicting the environmental impacts of proposed and ongoing energy-development activities, and (3) to demonstrate the environmental impacts of various activities and evaluate methods for minimizing adverse effects.

The Oak Ridge NERP is an integral part of the ecological programs administered through the Oak Ridge National Laboratory's Environmental Sciences Division. The core of the park is formed lby the land and water areas that ESD has used and protected for long-term ecological projects over the past 20 years. As part of the oak-hickory association of the ridge and valley province in the southern Appalachians, the Oak Ridge NERP includes a diversity of biological communities and a wide range of geology, topography, and cultural practices. Naturally occurring terrestrial and freshwater aquatic communities range from cedar barrens to streams and associated floodplains and upland hardwood forests, while current land uses include undisturbed mature hardwoods, intensively managed forest plantations, and power line corridors.

Recent major accomplishments in the Environmental Sciences Division are in the areas of acid deposition, global $CO_2$ and climate change, aquatic ecology, nuclear waste technology, and synthetic fuels.

Acid Deposition

- Threshold growth responses of some crop species exposed to acidic rain, sulfur dioxide, and ozone found to be close to pH 4.0.

- Foliar uptake of sulfur dioxide and ozone in kidney beans was dramatically stimulated by high humidity, suggesting a basis for regional differences on plant sensitivity to air pollutants.

- Potential impact of sulfate ions from acid rain on nutrient leaching in a southeast forest soil found to be mitigated by high sulfate adsorption in subsoil.

Global $CO_2$ and Climate Change

- Forest-growth simulation model, verified by pollen records, showed small ( $1^{\circ}C$) temperature changes may cause replacement of boreal forests by deciduous forests.

- Tree-ring bioclimatology successfully used to estimate spring precipitation in eastern Tennessee since 1700.

Nuclear Waste Technology

- Soil to plant transfers for technetium-99 near two gaseous diffusion plants was found to be one to two orders of magnitude less than published transfers measured using potted soils contaminated with pertechnetate ( $^{99}TcO_4$).

- Demonstrated that adsorption of strontium-90 can be increased three orders of magnitude by soil conditioning with alkali metal hydroxides.

- Found that migration of neptunium-237 and technetium-99 potential is influenced by geochemistry of groundwater.

- Uranium removal from municipal water supplies enhanced by $Mg(OH)_2$ chemical treatment.

Aquatic Ecology

- Developed nutrient spiralling model for stream ecosystems that incorporates interactions between nutrient transport and metabolic processes.

- An integrated compartment method was developed to provide computational algorithms to approximate partial differential equations for solutions of the physical dynamics of flowing water systems and other environmental media modeling.

- Modeling coupled with laboratory experimentation showed differential temperature-dependent ($20-27^{\circ}C$) juvenile growth of initially co-existing large and small-mouth bass to be important for population success.

- Completed evaluation of factors causing fish impingement at steam electric plants and recommended best available technology for protection devices.

- Determined that thermophilic amoebae pathogenic to man are present in power plant cooling lakes in northern latitudes.

Synthetic Fuels

- Initial development of an environmental assay for embryo toxicity and teratogenicity using the cricket Acheta domesticus (L.) (Science cover).

- Completed initial models for transport and fate of polycyclic aromatic hydrocarbons in aquatic environments.

- Found that microbiological action on sulfur bearing wastes produces acidic sulfate ions which in turn mobilize toxic elements.

- Determined effect of humidity on uptake and toxicity of ozone and $SO_2$ by vegetation.

## ORGANIZATION

The Environmental Sciences Division is organized into four sections and five programs (Figure 5). The programs are:

- Advanced Fossil Energy
- Fuels from Biomass
- Environmental Impact
- Low Level Waste Research and Development
- Toxic Substances

### Advanced Fossil Energy

Potential environmental problems associated with coal liquids technologies development are being identified in terrestrial and aquatic environments. Research emphasizes development of data for comparative technology assessments. Emphasis has shifted toward larger-scale, longer-term studies with initiation of pond experiments for assessing effects and fate of synthetic product spills.

The effects of effluents from coal conversion plants on aquatic organisms are of concern. Lethal and sublethal effects are being studied using effluents from different technologies, different organisms and different levels of organisms (individuals, populations, ecosystems). A battery of short term tests is being developed to predict safe concentrations of effluents. Treated effluents are being tested to see if treatment can ameliorate or eliminate toxicity. Contaminant fate and persistence are being studied with effects data to assess human health and environmental hazards. Comparative toxicity studies indicate that coal-derived liquids are generally more toxic than shale oil and petroleum products.

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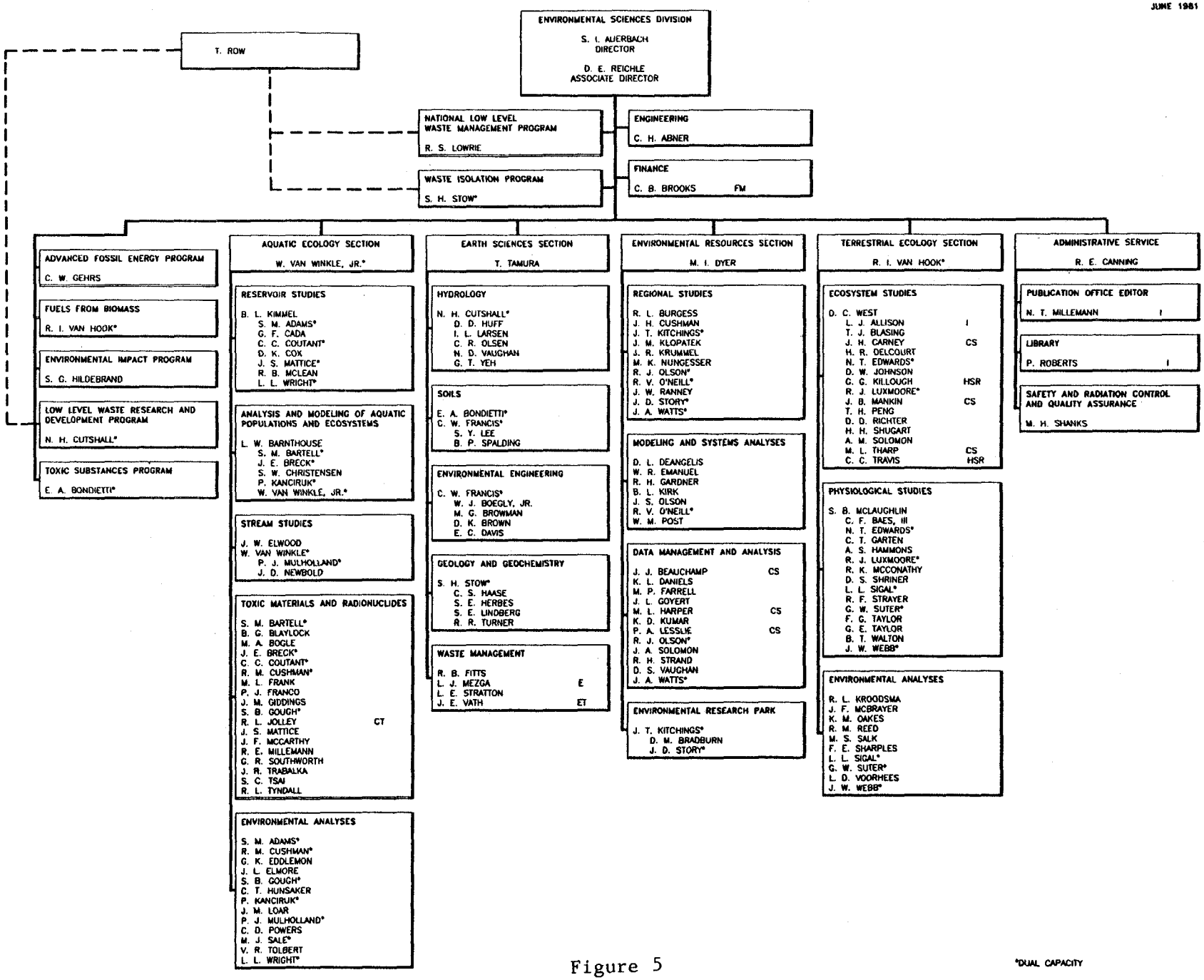



Figure 5

*DUAL CAPACITY

Liquefaction of coals will result in significant quantities of solid wastes (approximately 10% of the feedstock) which represent a major environmental concern because of their potential to contaminate surface and ground waters. The solid waste research has the primary goal of developing an understanding of the geochemical interactions of various wastes so that we can anticipate the fate of solid waste components in the environment. From these studies, recommendations will be made on chemical and physical mitigating measures to isolate the toxic elements. To minimize adverse environmental effects, the wastes need to be carefully characterized as to the degree of their hazardousness and placed in properly engineered landfills. A number of simple test systems were developed for testing the potential toxicity of solid waste to both aquatic and terrestrial organisms. The use of these test systems was extended to the identification of (1) potentially hazardous waste from coal gasification and liquefaction facilities and (2) potentially toxic water and soil that may have been contaminated with synthetic fuel oils. Studies were initiated to compare combustion and conversion ashes and to identify the potential role of microbial systems in mobilizing trace elements contained in the residues.

Fuels from Biomass

Fuels from biomass activities deal with production and harvest of wood for fuel and the environmental constraints associated with utilizing agricultural and forest residues for fuel. Woody biomass production studies are conducted by university, Federal, and private research organizations under the direction of Environmental Sciences Division staff.

Results to date showed that wood-energy plantations can be a viable source of supplemental energy in some locations ($22-25/dry ton), that production of 12 to 25 dry metric tons biomass $ha^{-1}$ $year^{-1}$ (5-10 tons $acre^{-1}$ $year^{-1}$) can usually be achieved on good sites in the East, Midwest, Pacific Northwest, and South, and that genetic improvement and species screening can raise this figure 25% or more in the first or second generation of selection efforts. The Southeast has the greatest potential for sustained wood-energy production, and surprising results occurred with semi-arid shrubs of the Southwest (35 metric tons $ha^{-1}$ $year^{-1}$ with irrigation).

Environmental effects of forest residue removal and whole-tree utilization beyond those caused by contemporary harvesting techniques are being studied at sites selected in northern hardwood (NJ), oak-hickory (TN), northwestern coniferous (WA), and southern pine (FL) forests. The selected sites, including one on the Oak Ridge Reservation, have large data bases of nutrient cycling in undisturbed systems providing a reference point for possible nutrient depletion and erosion. In addition, a slash pine experimental forest near Macon, Georgia, was selected for study to evaluate the long-term effects of repeated plantation harvest on productivity. Questions to be answered as a result of this research are: (1) What are the effects of total aboveground woody biomass removal on erosion and nutrient loss and subsequent changes in water quality? (2) What are the changes in nutrient supply? (3) What will these changes mean in terms of subsequent biomass productivity

under whole-tree or residue removal harvesting rotations? To date, all sites have been harvested following one year of base line measurements, and nutrient losses through biomass removal have been determined. Results suggest that N losses through whole-tree harvesting are insignificant compared to Ca losses; removal of 170 MT/ha at the Oak Ridge site results in losses of 1% P, 8% N, and 36% Ca.

Environmental Impacts Program

The Environmental Impacts Program (EIP) produces environmental analyses and assessment research related to Federal energy planning and decision-making processes. This includes preparation of Environmental Impact Statements (EISs), Environmental Impact Assessments (EIAs), development of environmental monitoring strategies and protocols, and promulgation of guidelines and environmental compliance documents.

The EIP is organized around seven team activities: Nuclear Power Stations, Nuclear Fuel Cycle, Geothermal Energy and Fuel Conversions, NEPA Affairs and Fossil Energy, Monitoring Protocols Development, Hydroelectric Projects, and Solar and Special Projects. The EIP projects directly related to the National Environmental Policy Act (impact statements and assessments) are cooperative efforts with the ORNL Energy Division, in which the EIP analyzes issues dealing with terrestrial and aquatic ecology and land and water use.

The primary goal of the Program is to promote the inclusion of scientifically sound and supportable environmental analyses and advice as input into major Federal decisions. To implement this goal the EIP engages in several activities which provide guidance, technical assistance, planning, and long-range environmental analyses.

The Environmental Impact Program activities at Oak Ridge National Laboratory have been an important means of identifying gaps in our understanding of the environmental impacts of energy technology development. Where sufficient information has existed to make firm judgments, projects have been approved, denied, or modified to lessen impacts. Where potential adverse impacts have been identified for which supporting information is lacking, research has been initiated at ORNL or elsewhere to facilitate more enlightened decision-making. Conversely, the close relationship between research and assessment within the Environmental Sciences Division promotes early recognition of potential impacts and rapid incorporation of research into Environmental Assessments and Environmental Impact Statements.

Toxic Substances Program

The Toxic Substances Program consists of two major areas of research. Radioecology and environmental chemistry research is conducted for DOE. Areas of importance include the actinide elements, particularly the transuranium group Pu, Np, Am, and Cm. Emphasis is on establishing their ecological distributions using historically contaminated sites. Other research for DOE includes terrestrial behavior of Technetium-99 near operating uranium enrichment plants, $^{95}$Np behavior in freshwater ecosystems, and radionuclide cycling in coastal environments. Staff

expertise in environmental chemistry of the artificial radioelements Pu, Np, and Tc has also assisted DOE waste management efforts in evaluating long-term migration questions in repositories.

Research and test development in the area of ecotoxicology is underway for EPA Office of Toxic Substances. The issue of multi-species test protocols for hazard assessments on new chemicals was recently addressed in the form of workshops and a review document. Several test protocols recommended for development are now under experimental evaluation. Single species test protocols are also being evaluated before incorporation into EPA's chemical assessment scheme. A multi-media modelling project is expanding the ORNL Unified Transport Model to include toxic substances (organics). This model will assist EPA in evaluating chemical dispersion and potentials as part of a chemical assessment.

Low-Level Waste Research and Development Program

When radioactive contamination levels are relatively low, it is cost effective to dispose of solid wastes by shallow land burial. This project provides for the development and implementation of new methodologies in environmental monitoring, updating of existing procedures, and standardization of monitoring criteria for all present and future burial facilities. These guidelines, with appropriate modifications, may be extended to encompass alternative disposal options to shallow land burial, such as deep disposal in geologic formations.

The most significant mechanism for transport of radionuclides from shallow land burial sites in the humid eastern United States is groundwater flow. Water flowing laterally into buried waste or percolating downward from the surface leaches radionuclides from the waste, continues to flow spreading the contamination. Several radionuclides, especially $^{90}Sr$, are found in solution in ground water flowing from older burial sites. Methods for immobilization of such radionuclides or for their collection and removal are urgently needed. Furthermore, the continued development and implementation of improved shallow land burial practices is necessary.

The overall goal of this work is to develop the necessary technology to ensure the safe, economical, and environmentally and socially acceptable disposal of solid low-level radioactive wastes. Specific objectives include studies of the mechanisms whereby radionuclides are mobilized and transported (or, conversely, retained) at shallow land burial sites, of development and evaluation of measures for prevention of mobilization, and development and evaluation of measures for correction of radionuclide dispersion problems at older sites.

Low-level waste storage areas at Oak Ridge National Laboratory are used as a testing and proving ground for monitoring and modeling techniques. Because of the range in age of the ORNL waste storage areas and the similarity of hydrologic and topographic conditions to much of those of the eastern United States, these areas provide an excellent setting for real world assessment of methods.

The four sections in the Environmental Sciences Division are:

- o Aquatic Ecology
- o Environmental Resources
- o Earth Sciences
- o Terrestrial Ecology

Aquatic Ecology

The Aquatic Ecology Section is involved in basic and applied research focusing on environmental problems and on gaining a better understanding of the structure and function of aquatic ecosystems. The continuing objectives of the section are to develop and maintain a position of excellence in disciplinary areas of aquatic ecology, to provide technical expertise to achieve the goals of the various Division programs, and to anticipate future disciplinary and programmatic directions of research in aquatic ecology.

The Reservoir Studies Project involves research on ecological issues related to small-scale hydroelectric development. These studies also focus on the more basic questions of assessing the effect of low temperatures on mortality of threadfin shad and of identifying the resiliency mechanisms operable within the threadfin shad population. Studies of trophic dynamics of reservoir benthos focus on determining the direct and indirect effects of a power plant on mayflies and the Asiatic clam, Corbicula. Studies of habitat selection by predators involve investigating the role of physical factors, particularly temperature, in determining habitats selected by major predatory fish species and investigating the relationship of selected habitat to prey utilization and physiological performance. Work in the small-scale hydro project focused on analyzing the potential environmental impacts associated with dredging, with water level fluctuations, and with fish passage both upriver and downriver.

The second major project in the section involves analysis and modeling of aquatic populations and ecosystems. A variety of useful quantitative methodologies were developed and applied in an effort to assess the impacts of entrainment and impingement of fish by power plants along the Hudson River in New York. The resultant methodologies are proving to have applicability to a variety of other systems and populations, with particular emphasis on evaluating the effects of toxic materials at both the population and community levels. Efforts have been concentrated in the areas of formulation of physicochemical processes; operation of the Unified Transport Model; and development, verification, and validation work on atmospheric, terrestrial, and aquatic transport models.

Pathogenic microorganisms in artificially heated waters is a growing area of concern. Our research is focused on determining the extent of distribution of pathogenic amoeba and bacteria, such as the Legionnaires' Disease Bacterium, and on defining the conditions promoting their proliferation.

Environmental Resources

Specific groups within the section are Regional Studies, Modeling and Systems Analysis, and Data Management and Analysis. Regional studies historically have focused on site-specific subjects which mainly characterize conditions involved in potential impacts. Such studies are closely tied to extant data bases or the collection of new data to meet new objectives in regional analysis. The value of such studies will continue, but additional approaches are being developed to help managers plan and predict alternatives relating to overall land use in a given region. Systems analysis activities continue to be closely allied with research project planning and analysis. In addition, staff are active in the development of new system analysis approached to determine how uncertainty can be handled with greater confidence when dealing with natural systems. Section staff provided considerable development and aid to ESD and outside agencies in numeric data activities through statistical and computer analyses in the past year. Further, continued acquisition, organization, updating, and use of both extant and newly collected data added significantly to ESD resources and capabilities.

Earth Sciences

Most of the contributions of the Earth Sciences staff are directed to accomplishing the missions of programs within the Environmental Sciences Divison; these include the Synthetic Fuels, Nuclear, Low-Level Waste, and the Multimedia Modeling programs. A continuing growth area is represented by the Nonnuclear Solid Waste Technology efforts.

RCRA requires that all nonhazardous wastes be disposed in sanitary landfills. In the past, the term sanitary landfill was poorly defined; in fact, some open dumps were called sanitary landfills. The EPA has now published a new set of regulations concerning land disposal of nonhazardous wastes titled "Criteria for Classification of Solid Waste Disposal Facilities and Practices" (44FR 53438-53464). Efforts are underway to evaluate the applicability of the EPA-leaching procedure in classifying different solid waste landfills in the country. Companion studies are also underway to develop a leaching and concentrating technique for organic waste types.

Investigations of impervious liner development and sealing techniques of trenches are part of an overall program on environmental control technology. As part of potential environmental control application effluents from combustion and gasification plants are being characterized in terms of leaching as well as associated chemical states.

Terrestrial Ecology

The Terrestrial Ecology Section provides expertise in terrestrial environmental sciences to both basic and applied research areas. The section is currently involved in ecosystem studies, environmental impacts, advanced fossil energy, and nuclear programs. Within the section, a basic research program is maintained to ensure continued development of our technical abilities in selected areas of terrestrial ecology. Current section research encompasses three major areas: ecological effects of air pollutants, element cycling studies on Walker Branch Watershed, and ecosystem studies.

Research activities on ecological effects of air pollutants are aimed at evaluating both present and future ecological risks associated with pollutants from coal combustion and other energy technologies. Initial results using the recently completed controlled fumigation facility indicate that increasing humidity causes a substantial increase in foliar uptake of both ozone and $SO_2$. Results from studies of acid precipiation on vegetation indicate (1) that rain pH effects are direct on foliage rather than indirect through interactions within soil, (2) that the combined effects of ozone and increasing rain acidity are greater than additive, and (3) that plant response to acidic precipitation is further confounded by genetic differences among plant species and cultivars.

Research on atmospheric deposition in the field focused on identification of organic constituents in rain above and below a forest canopy. Extracted material observed in throughfall samples proved to be largely aliphatic and was identified by comparison of experimental mass spectra. Organic acids and plasticizers were found in all samples. Chlorinated organic compounds were also observed, as were turpinoids derived from coniferous vegetation. Rainfall samples included all compounds found in throughfall, but at considerably lower concentrations.

Acid precipitation and soil mobility studies continued to concentrate on the development of a working hypothesis for why certain soils leach sulfate anion and others do not. Results to date indicate that the presence of free iron and aluminum account for considerable sulfate absorption in watersheds in East Tennessee, North Carolina, and Costa Rica. In contrast, watersheds in New Hampshire and Washington accumulate none of their incoming sulfate and are being leached. Our studies will continue to examine the role of acid rain versus naturally produced acid, determine the role of organic matter in types of free iron and aluminum in sulfate absorption, and ultimately develop simple soil criteria for susceptibility to leaching by sulfuric acid.

Hydrologic research further developed the variable source-area concept and to understand the role of soil macropores in the subsurface flow of water. Hydrologic consequences of soil macropores were investigated with a modified version of our hydrology model by including algorithms for macropore flow. Initial runs indicate that macropores can cause a major change in simulated drainage patterns under high rainfall conditions.

Bioclimatology studies focused on establishing a sound basis for both tree-ring and pollen chronology work in the southeastern United States. We recently showed that climate can be reliably reconstructed from tree-ring data in East Tennessee and Iowa. When the simplest form of statistical analyses was used, our correlation coefficients between actual and reconstructed values were significant at the 99% confidence level in 12 of the 13 sites analyzed. These coefficients are based on 40 years of independent data at each site.

# HEALTH AND SAFETY RESEARCH DIVISION

## INTRODUCTION

The programs of the Health and Safety Research Division encompass a broad range of basic and applied research defining how energy-related technologies affect man. Approximately one-third of the effort is in basic studies at atomic and molecular levels and is supported almost entirely by DOE's Office of Health and Environmental Research. The fundamental physics research (photophysics, biophysics, surface physics, etc.) deals with processes that are important to understanding the formation, mobility, toxicity, detection, and characterization of pollutants that might affect man. Some of this research is associated with programs that have been funded continuously for over thirty years.

The remainder of the Division's programs are of a more applied nature and receive more diverse funding from within DOE and other agencies. The applied research activities include the integration of data from basic and applied studies through development of concepts and methods that focus on the health and safety of man. This capability is complemented by expertise in ecological assessments in the Environmental Sciences Division and socioeconomic analysis in the Energy Division. The Division has a unique responsibility for evaluating the health risk associated with exposures to specific energy-related pollutants. Major strengths lie in the applied programs in measurements, transport modeling, dose estimation, and health risk analysis.

Some of the Division's special skills include: negative ion physics, electron- and ion-molecule interactions, electron attachment and detachment processes, laser spectroscopy, wake theory, gaseous dielectrics, nuclear medicine, modeling radionuclide transport to man, radiation dosimetry, decontamination and decommissioning surveys, developing and testing instrumentation to measure exposures of humans to chemicals, and uncertainty analysis of assessment models.

A selection of some recent accomplishments are the following:

Instrument Development

- Developed a technique to use lasers to vaporize atoms from a solid surface and subsequently identify single atoms of a given type of resonance ionization spectroscopy.

- Resonance ionization spectroscopy was used for the first direct counting of noble gas atoms.

- Observation of a new laser-induced "collective excitation" phenomenon in rare gases, with strong generation of ultra violet light.

- Tested the Derivative Ultra Violet Absorption Spectroscopy (DUVAS) at the University of Minnesota-Duluth gasifier and the H-Coal facility at Catlettsburg, Kentucky.

- Developed a lightpipe luminoscope for detecting skin contamination by oil and tar.

- Developed a new compact transmission soft x-ray spectrometer.

- Developed "fast gases" for radiation counters.

- Received IR-100 Award for portable spill spotter for detecting organic pollutants on surfaces.

- Development and evaluation of new $^{123m}$Te-labeled fatty acids for heart imaging.

New Research Techniques

- Radiolabeled barbiturates prepared for the first time as a new class of cerebral blood perfusion agents.

- Developed a methodology for analyzing and quantifying the uncertainty associated with assessment model predictions.

- Developed new technique to calculate electron energy-loss mechanisms in irradiated liquid water including early events that occur prior to the time that a chemical reaction is dominant.

Nuclear Programs

- New secondary radiation protection limits were computed at ORNL and issued by the International Commission of Radiological Protection (ICRP Publication 30) for about 750 radionuclides.

- Assisted in the improvement of neutron dosimetry on an international scale by conducting and analyzing the 6th Personnel Dosimetry Intercomparison Study and the 17th Nuclear Accident Dosimetry Intercomparison Study using the HPRR.

- Performed the first continental-scale (U.S., Canada, and Mexico) radiological assessment of exposures due to radon daughters based on site-specific data.

- Given leading role for initial radiological surveys and final certification measurements of original Manhattan Engineer Projects.

- Troyce Jones was presented the 1980 Elda E. Anderson Award by Health Physics Society for his contributions to the field of health physics.

- Dr. Loucas G. Christophorou was named a Corporate Research Fellow of Union Carbide.

## ORGANIZATION

The Health and Safety Research Division is organized into four sections and the Office of Integrated Assessment and Policy Analysis (Figure 6). The sections are as follows:

- o Biological and Radiation Physics
- o Health Studies
- o Chemical Physics
- o Technology Assessments

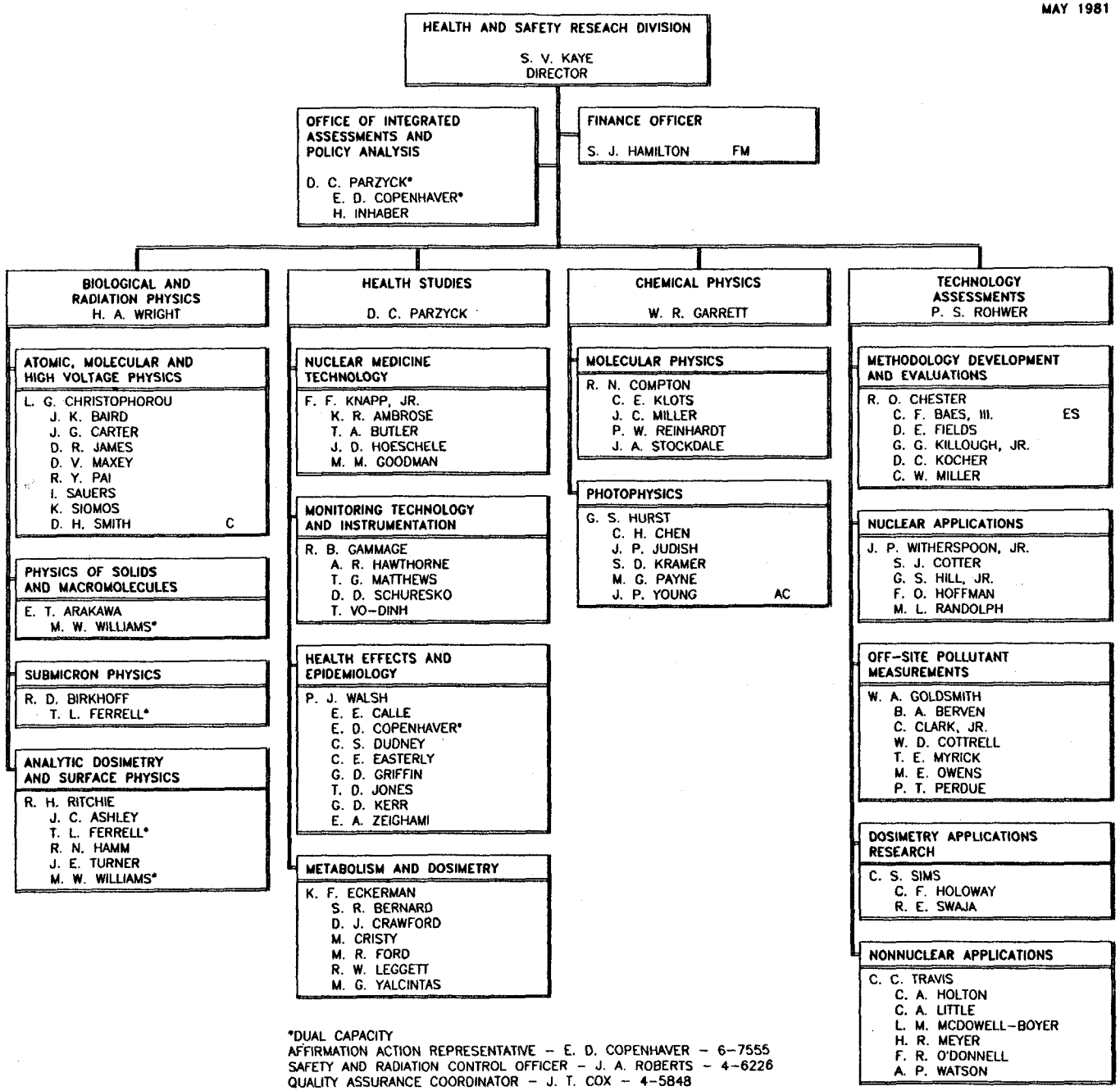
Information about research in each of the sections is given.

### Biological and Radiation Physics

Research activities consist primarily of basic studies of the fundamental properties of matter in all phases (gas, liquid, and solid) and are directed toward providing information on topics such as the structure and properties of materials of biological importance, the physical processes that are important in the transport of pollutants through the atmosphere, and the interactions of pollutants with biological materials. Because most biological materials exist in the solid or liquid phase and the pollutants must interact at surfaces in biological systems, the section has a vigorous research program involving the study of properties of materials in the condensed phase and of interaction mechanisms and energy transfer processes within and at the surfaces of condensed media. In the study of atomic molecular interactions, researchers have succeeded in making accurate and quantitative measurements of the effects of density on the motion of slow electrons through dense polar gases. Two techniques -- integrated fluorescence and laser to photon ionization -- have been developed for the study of one- and two- photon ionization processes in liquids.

In the broad area of surface physics, efforts of the Health and Safety Research Division are directed at illucidating the fundamental physical mechanics involved in interactions of both microscopic and macroscopic particulates with condensed matter surfaces. To supplement existing classical theories, the quantum theory of the image potential was developed. Some specific problems studied include dynamic and geometric effects on the physical absorption of atoms, particle trajectories under the influence of an image potential, and deposition of charged particles from laminar flow in cylinders. In collaboration with the Biology Division, the behavior of heavy metals in living systems is being characterized and the physical parameters appearing to correlate with toxicity are being determined.

The section has established a significant program in high voltage research. The program emphasizes studies of basic phenomena underlying dielectric behavior and the development of improved dielectrics to permit higher transmission efficiencies and greater reliability of switching devices. Elucidation of the fundamental physical parameters governing dielectric behavior under high voltage loads and impulses to lead into studies of the toxicity of various gaseous and liquid dielectrics as well as their degradation products.




*DUAL CAPACITY
AFFIRMATION ACTION REPRESENTATIVE – E. D. COPENHAVER – 6-7555
SAFETY AND RADIATION CONTROL OFFICER – J. A. ROBERTS – 4-6226
QUALITY ASSURANCE COORDINATOR – J. T. COX – 4-5848

Figure 6

## Health Studies

The Health Studies section has as its principal mission the development of analytical techniques to characterize health risk associated with a variety of technology-related activities and the development of radiolabeled substances for application in biomedical research. Analytical approaches developed by staff within this section range from those necessary to determine the extent of pollutant exposure to those necessary to determine the extent of health risk resulting from technology-related activities.

The Nuclear Medicine Technology group has widespread recognition in design, synthesis, and animal testing of new radiopharmaceuticals for use in clinical nuclear medicines and other radiolabeled agents for fundamental biomedical research. Vigorous medical cooperative programs with prestigious clinical research groups enable the researchers to evaluate clinical results quickly.

The monitoring technology and instrumentation group developed instrumentation to determine the nature and extent of exposure to noxious substances in the outdoor environment, the work place, and the home. Instrumentation development for pollutant detection in measurements emphasizes real or near-real time monitoring of chemical pollutants. The major role of the instrumentation group is in health protection in support of the Laboratory's synfuels program. In addition, expertise in this area is being applied to monitors for products of coal combustion, indoor air pollution, toxic chemical disposal and accident and spill analysis. Measurements of non-nuclear pollutants in the work environment are being conducted with a portable mass spectrometer, a second derivative ultraviolet absorption spectrometer (DUVAS), and a lightpipe luminoscope for examination of contaminated skin. The results provided by the techniques are in good agreement with those obtained using more elaborate high-performance liquid chromatography and gas chromatography/-mass spectroscopy techniques.

Work on generalized methods for treating risks from nuclear and non-nuclear technologies on a common scale has continued. The primary thrust for carcinogenic risk has been to develop a unifying hypothesis of all carcinogenic insults based on the initiation, promotion, and competing risk aspects of carcinogens and cofactors. These guidelines will be used ultimately in composite hazard indices to prioritize nuclear and non-nuclear hazards. In addition to projects pertaining to specific epidemiological research, methodological approaches for estimating disease risks are being developed. The metabolism and dosimetry group investigates the metabolic behavior of technology-generated substances and determines the radiation dose from substances associated with the nuclear fuel cycle. The effort to translate the primary radiation protection guidance set forth by the International Commission on Radiation Protection in publication into secondary limits has been completed. These limits, in the form of annual limits of intakes and derived air concentrations, are published in the Commission's publication 30 and supercedes the secondary limits of publication 2 issued in

1959. Efforts continue toward development of dosimetric methodologies for age-specific considerations. Age-dependent physiological models for the respiratory and gastrointestinal tract and models for retentions of systematic burdens are under development.

Chemical Physics

Activities in the Chemical Physics section consist of basic physical and chemical studies that are relevant to energy-related problems in atmospheric physics and chemistry, radiation chemistry, pollutant detection technology, laser development, and analytical applications of laser techniques. Experimental techniques employed in these research efforts include molecular beams, mass spectroscopy, sonic-nozzle-jet molecular-cluster sources conventional laser spectroscopy, multiphoton ionization, and saturated resonance ionization spectroscopic methodologies.

The division holds a prominent position in laser-related research. The scope of the work includes unique applications of optical techniques to basic atomic and molecular physics studies, solid state and surface studies, and the development of new analytical techniques by involving high-resolution, high-power tunable laser systems. Solutions to the difficult task of characterizing and identifying complex organic and inorganic molecules is being sought through laser fluorescence studies of rotationally and vibrationally cooled molecules and through the recently developed technique of two-color multiphoton-ionization mass spectroscopy. In addition, techniques of resonance ionization spectroscopy (RIS) and one-atom detection are being used in the studies of particle tract structure, one-atom chemistry, studies of neutral particle diffusion and for detection of nuclear isomers and solar neutrinos for measuring ocean water turnover rates and for very sensitive detection of Carbon-14.

Whereas RIS grew out of earlier work on energy pathways and radiated gases, it is now used to study the fundamental processes themselves. When completed, a new machine called Maxwell's Demon should be able to count a few atoms of a particular isotope (A) even when a neighboring isotope A+1 is more abundant by $10^{12}$ or greater. Such a capability is needed in solar neutrino research and experiments involving neutrino oscillations and $\beta$-$\beta$-decay and in problems of oceanography, geochronology, polar icecap dating, waste isolation, and neutron dosimetry.

Technology Assessments

A broad spectrum of projects have as their common focus the development, evaluation, and application of methodologies for assessing impacts on man due to effluents released to the environment via energy technology research, development, and implementation. Laboratory and field elements of this section's programs are dominated by measurement and survey activities in support of the Department of Energy's (DOE) Formerly Utilized Sites for Remedial Action Program (FUSRAP) and by applications of the Health Physics Research Reactor (HPRR) in mixed field neutron- and gamma-ray dosimetry research. Theoretical elements of the

section's programs are dominated by activities to develop and apply concepts, models, computer codes, and data bases for quantitative simulation of pollutant movement from point of release to point of exposure for man with subsequent estimation and evaluation of potential impacts on individuals and populations.

Although nuclear assessment activities continue to require a large proportion of the available resources, major emphasis is now directed to non-nuclear pollutants. The non-nuclear assessment effort is a combination of developing new concepts specific for the purpose and of adapting existing radiological methodologies. The program is wide in scope and encompassing exposure of occupational workers and the general public for both routine and accidental releases. The development of mathematical models and computer codes to assist in predicting the environmental transport of toxic pollutants and the assessment of health and safety risks associated with development and operation of energy technologies has been emphasized.

In the nuclear applications group assessments of both operating and decommissioned nuclear fuel cycle and non-nuclear fuel cycle facilities were performed. The Division has played a lead role in documenting the present radiological status of sites associated with the Manhattan Engineer District (MED) and the Atomic Energy Commission (AEC) and any vicinity properties which may have inadvertently been contaminated. After remedial action has been performed by other contractors, the Health and Safety Research Division group conducts further radiological surveys at each site. A mobile gamma radiation scanning van was developed to locate and determine the source of anomolously high gamma radiation in the vicinity of the MED/AEC sites.

The HPRR is an excellent research facility maintained within HASRD. The HPRR is a small, unshielded, unmoderated, fast reactor which can be operated to yield up to $10^{17}$ fissions in the pulse mode and can operate up to 10 kW in the steady-state mode. The program using the HPRR features radiobiological research, dosimetry research, education, and training. The radiobiological research and education and training activity involve other DOE contractors, other research organizations, and schools in the surrounding area. Present emphasis of the dosimetry research program is on nuclear accident dosimetry and the personal dosimetry intercomparison studies. Researchers, vendors, and users expose their dosimeters to known radiation fields and compare their results. The purpose is objective comparison of dosimetry systems in the interest of establishing reasonable expectations for the systems presently in use and improvement in state-of-the-art.

Office of Integrated Assessments and Policy Analysis

This office was established to develop research into the policy implications of energy-related Federal legislation and to support multidisciplinary studies of the impacts associated with a variety of energy-related activities. Most recently this office has continued investigation into

the impact and control of hazardous waste. The goal has been development of a range of evaluated options for inclusion in the siting processes, including incentive, compensation mechanisms for risk, damages, and long-term line commitment, state and local participation, local verification and monitoring, and mediated negotiations. Emphasis has been placed on determining when, how, and if mitigating measures are sufficient as incentives and if not, what constitutes true incentives.

Along with studies into hazardous waste facility siting, the office has investigated the health and environmental risk associated with the production of liquid fuels from coal. An interdisciplinary group has been formed with representatives of the Health and Safety Research, Chemical Technology, Environmental Sciences, Biology, and Information Divisions to consider these risks. The main purpose of this research is to provide identification of the principal health and environmental impacts of this technology and to quantify the extent of the impacts wherever possible.

# INFORMATION CENTER COMPLEX

## INTRODUCTION

The Information Center Complex (ICC) is a constituent of the Information Division of the Oak Ridge National Laboratory (ORNL). Since its beginning in 1971, ICC has rapidly evolved from a small core to a versatile, multidisciplinary organization engaged in all phases of scientific and technical information management, assessment, and transfer. In addition to providing information support services ranging from query responses and current awareness services to abstracted and keyworded bibliographies, ICC performs major tasks in response to concerns of national and international importance. These include:

- developing new data bases for specific areas in toxicology, environmental concerns, air and water pollution, management and transportation of hazardous wastes, and energy resources and conservation;

- participating in a series of workshops on genetic toxicology, providing all pertinent documentation to the participants, computerizing the results, and preparing follow-up reports used in regulatory and decision-making processes;

- publishing comprehensive state-of-the-art and assessment reports on topical subjects in cooperation with government agencies and other organizations.

ICC's programs are focused on three major areas:

- Environmental and Health Effects of Toxic and Hazardous Substances
  - Chemical toxicity
    - Mutagenicity
    - Teratogenicity
    - Carcinogenicity
  - Environmental transport and interactions
  - Radiation effects

- Energy Resources, Production, and Utilization
  - Environmental impact
  - Engineering
  - Policy and legislation
  - Economic assessments

- Waste Disposal
  - Nuclear waste
  - Chemical waste

Recent major accomplishments of the ICC are:

- o National Symposium "Pespectives on Scientific and Technical Information;"
- o Developed a $CO_2$ Information Center in support of the ORAU/ORNL Assessment team for numeric data handling, data base building, and literature support;
- o Initiated Risk Assessment data base; provided support to ongoing risk assessment projects;
- o Scientific Rationale for the Selection of Toxicity Testing Methods: Human Health Assessment;
- o "Technologically Enhanced Natural Radioactivity;" published report used in the remedial action program to explain radiological contamination where no known fuel cycle activities were conducted;
- o Staff of the Environmental Mutagen Information Center awarded the Environmental Mutagen Society 1980 Environmental Mutagenesis Award for "establishing an outstanding prototype information service which has greatly facilitated research in the field of mutagenesis."

## ORGANIZATION

Organizationally, ICC comprises nine major units that perform particular tasks according to their mission (organization shown in Fig. 7):

- o Environmental Mutagen Information Center
- o Environmental Teratology Information Center
- o Toxicology Data Bank
- o Toxicology Information Response Center
- o Center for Energy and Environmental Information
- o Ecological Sciences Information Center
- o Fossil Energy Information Center
- o Chemical Effects Information Center
- o Radiation Effects Information Center

### Environmental Mutagen Information Center

The Environmental Mutagen Information Center (EMIC) collects, organizes, and disseminates information of relevance to the field of genetic toxicology.

Information in the EMIC data base is obtained from reports in the open literature relating to mutagenicity testing of environmental agents. There are currently over 36,000 entries from approximately 2,700 sources, most published since 1968. Each record contains bibliographic information, assay systems and/or biological endpoints, and keywords defining agents tested and organisms studied. Chemical Abstracts Service registry numbers are provided for all unique chemical agents.

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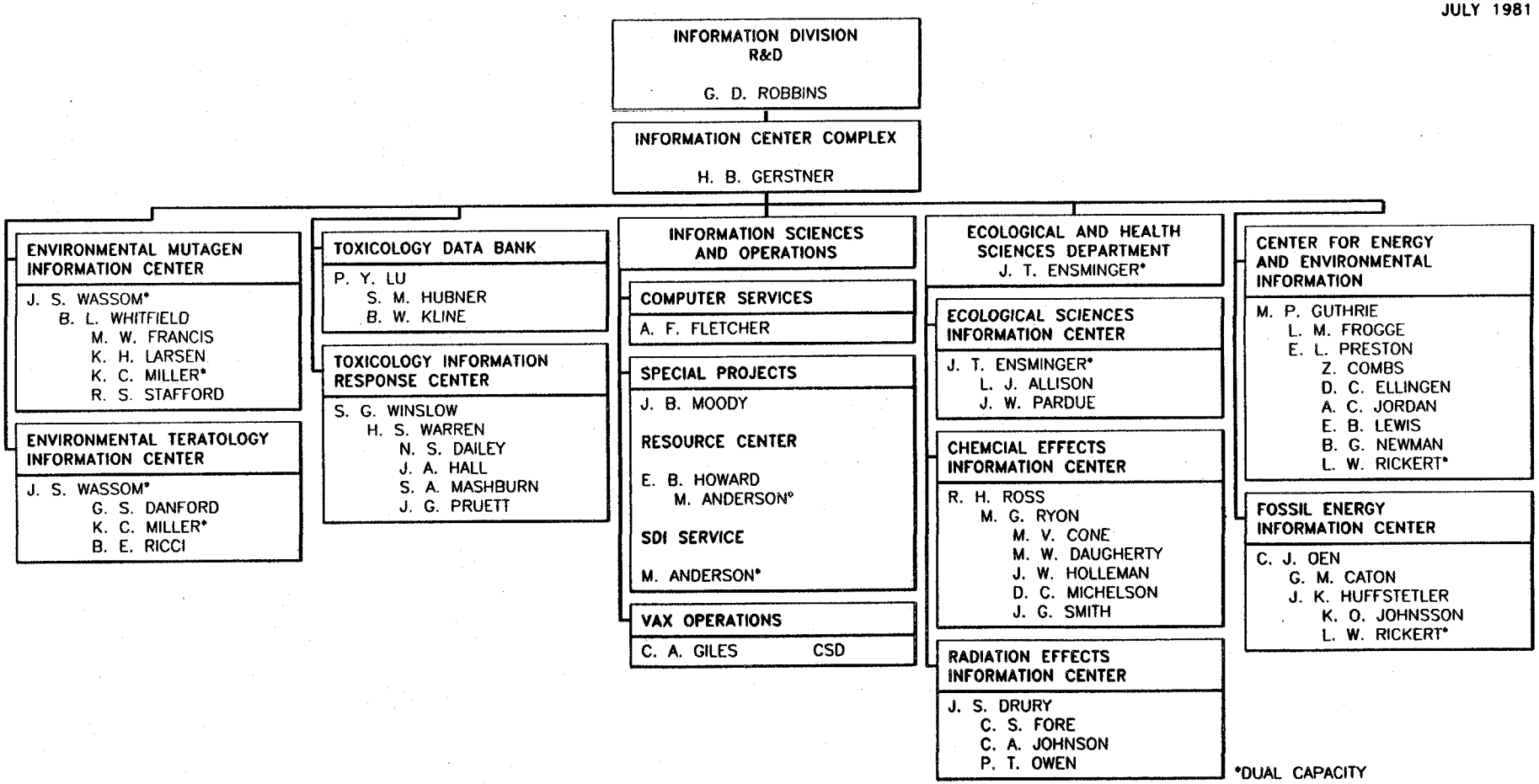


Figure 7

Information on approximately 12,000 different chemical agents is contained in the data file. The EMIC data base is accessible on-line from the National Library of Medicine's TOXLINE system and the Department of Energy's RECON system. Information services available from EMIC are literature surveys, indexed bibliographies, and bibliographic references on specific agents, organisms, and other indexed terms.

Environmental Teratology Information Center

The Environmental Teratology Information Center (ETIC) collects, organizes, and disseminates information on the evaluation of chemical, biological, and physical agents for teratogenic activity. Easy access to this literature facilitates health assessment and research planning and prevents duplication of effort in the field of environmental teratology.

There are currently more than 24,000 entries from approximately 2,200 sources in the ETIC data base. Each entry contains bibliographic details and keywords defining agents tested, biological endpoints observed, and organisms studied. Chemical Abstracts Service registry numbers are provided for all unique chemical agents. Information is available on approximately 5,500 different chemical agents. Information services provided by ETIC are literature surveys, indexed bibliographies, and bibliographic references on specific agents, organisms, biological endpoints, and other indexed terms.

Toxicology Data Bank

The function of the Toxicology Data Bank (TDB) is to provide an on-line interactive file of chemical, toxicological, and environmental information on selected chemical substances that are potentially hazardous to human health and environmental quality.

The TDB contains over 60 different data elements, such as:

- synonyms
- chemical and physical properties
- Chemical Abstracts Service registry number
- human toxicity
- nonhuman toxicity
- aquatic toxicity
- analytical laboratory methods
- interactions
- absorption, distribution, and excretion
- metabolism
- antidote and treatment
- modes of action
- consumption pattern
- safety and health precautions
- disposal methods
- environmental pollution potential

- o poisoning potential
- o radiation hazards
- o threshold limit values
- o pharmacology and toxicology
- o manufacturing information
- o fire potential and freighting methods
- o occupational exposure and limits

There are 2,500 records currently available on TDB through the National Library of Medicine.

Toxicology Information Response Center

The Toxicology Information Response Center (TIRC) serves as a national and international center for the collection, analysis, and dissemination of toxicology-related information. TIRC provides information on a variety of chemicals, including food additives, pharmaceuticals, industrial chemicals, environmental pollutants, heavy metals, and pesticides.

TIRC staff members acquire, select, store, retrieve, evaluate, analyze, and synthesize comprehensive literature search packages in response to requests from users. Interested persons may request specific published toxicology data, customized literature searches, topical bibliographies, annotated and/or keyworded bibliographies, state-of-the-art overviews, individually profiled searches of computerized data bases, selective dissemination of information service, access to over 650 literature searches generated annually, and use of the Center's toxicology library. In addition, selected reports authored or prepared by TIRC staff members are available through the National Technical Information Service. Publication lists, information brochures, and associated fact sheets are available from the Center upon request.

Center for Energy and Environmental Information

The Center for Energy and Environmental Information (CEEI) provides programmatic and information R&D support to ORNL and Department of Energy (DOE) programs in the interdisciplinary areas of energy and the environment. The scope of CEEI's activities includes:

- o buildings' energy conservation and consumption
- o cogeneration and district heating
- o data validation
- o energy conservation
- o energy technologies assessment
- o energy supply/demand and econometric models
- o legislation and policy analysis
- o regional studies
- o solar and decentralized energy technology
- o transportation

In addition to response to technical queries, CEEI services and products include newsletters, fact sheets, literature overviews and state-of-the-art reports, information critiques, bibliographies, and workshop and symposia support. Recent CEEI publications have covered varied topics such as residential conservation, hazardous wastes, environmental contaminants, and environmental impact assessments of energy technologies. The CEEI staff has provided support for siting guides, data validation analyses, national policy assessments, handbooks for environmental monitoring of coal conversion facilities, and energy conservation and energy use data books. For the Residential Conservation Service program, CEEI staff have collaborated in the preparation of program guides, fact sheets, and a model audit. CEEI has constructed public comment data bases for the Residential Conservation Service and the Buildings Energy Performance Standards programs.

Ecological Sciences Information Center

The Ecological Sciences Information Center (ESIC) has as its primary concern the acquisition, analysis, and dissemination of technical information related to power plant effects and the carbon cycle. Activities include performing customized information searches, development of data bases and bibliographies, and writing state-of-the-art reviews. A series of information files has been compiled on the environmental impact of electric generating stations. Major data bases include impingement, entrainment, and the effects of temperature, chlorine, and ozone in cooling waters discharged to the environment. Other data bases created to aid in the assessment of power plant impact focus on biofouling, life histories of several fish species, and cooling towers. The carbon dioxide project is concerned with information on the carbon cycle and the possible climatic impact of increased atmospheric carbon dioxide. The data base covers the fields of physics, chemistry, climatology, engineering, economics, and political and social sciences.

Fossil Energy Information Center

Emphasizing the needs of ORNL fossil energy research, the Fossil Energy Information Center (FEIC) collects, analyzes, and disseminates information on various facets of fossil energy, including engineering, basic physical sciences, characterization, health and environmental effects, coal conversion technologies, and coal combustion.

FEIC provides current awareness tools, constructs specific searches from the large commercial data bases available in machine readable form at ORNL, and develops specialized technical data bases. Reviews, state-of-the-art reports, bibliographies, and other types of publications are also produced, resulting in a full range of information products.

Chemical Effects Information Center

The Chemical Effects Information Center (CEIC) provides information support to scientific and administrative communities concerning health and environmental effects of chemical pollutants. This support may be in the form of state-of-the-knowledge reviews such as "Cadmium in Foods"

and "Review of the Environmental Effects of Fluoride," or health and environmental assessment reports such as "Levels of Chemical Contaminants in Nonoccupationally Exposed U.S. Residents" and "Scientific Rationale for the Selection of Toxicity Testing Methods: Human Health Assessment," or specialized chemical data bases and catalogs such as "Chemicals Tested for Phytotoxicity" and "Chemicals Identified in Human Biological Media." CEIC has a staff of multidisciplinary technical personnel who hold advanced degrees in one or more of the following areas: biology, biochemistry, chemistry, ecology, environmental sciences, nutrition, and pharmacology.

Radiation Effects Information Center

The Radiation Effects Information Center (REIC) collects, analyzes, and disseminates technical information related to effects produced by radioactive substances. REIC is primarily concerned with nuclear fuel cycle studies, including health effects, costs, and environmental impacts of transporting, storing, and disposing of nuclear fuels. REIC has developed and currently maintains a large group of interlocking computerized information files pertinent to nuclear fuel technology. These include files on low-level radioactive waste technology, high-level nuclear waste isolation, decommissioning of nuclear facilities, and transportation technology legislation. In addition, REIC maintains a computerized data base defining limits of intake of radionuclides by workers as determined by the International Commission for Radiation Protection, and a risk assessment data base by which human health risks can be more readily evaluated. Other REIC activities include publishing bibliographies and a quarterly newsletter, Radioactive Waste Technology Newsletter, performing customized information searches, and preparing specialized reports, such as Uranium in U.S. Surface, Ground, and Domestic Waters, which required assessment of approximately 100,000 records collected from each of the fifty states.

## OTHER BIOMEDICAL AND ENVIRONMENTAL PROGRAMS

Other divisions within the Laboratory in addition to the ones already mentioned are involved in biomedical and environmental research. The divisions are:

- o Analytical Chemistry
- o Chemical Technology
- o Computer Sciences
- o Energy
- o Instrumentation and Controls

Brief examples of some of the work in these divisions is given in the following.

Analytical Chemistry. Efficient, cost-effective analytical methods, and instrumentation for the determination of workplace and environmental contaminants are being developed. Process, occupational, and environmental samples from coal conversion plants are being taken and analyzed. Ammonia chemical ionization mass spectrometry, nuclear magnetic resonance, and infrared spectroscopy are used in combination with chromatographic separations to identify alkaline and neutral mutagens. Other projects involve the characterization of aerosols produced from diesel fuels and cigarette smoke.

Chemical Technology. Fundamental relationships in areas of bioengineering research, particularly with regard to microbial and enzyme engineering, and monitoring and separation techniques as they apply to energy-related processes are being explored. Biological treatment methods are being studied for aqueous effluents from coal gasification and liquefaction. Constituents amenable to biological treatment include phenols, thiocyanates, ammonia, nitrates, and other carbon compounds. Advanced high-flow-rate bioreactor designs (e.g., fixed-film, fluidized-bed) are being developed and tested using both real and simulated effluent streams.

Instruments are being developed for environmental monitoring problems associated with coal conversion and shale oil production. A single cell microfluorometer is being developed to monitor exposure of plant personnel to polynuclear aromatic hydrocarbons. H-coal process streams and plant effluents are being chemically and physically characterized by on-line and in-plant sample collections and measurements. Control technologies are being tested on coal conversion wastewaters, sludges, and gaseous effluents.

Computer Sciences. Statistical and mathematical advice is given to biologists for planning and analyzing experiments. Better methods for handling statistical problems are being researched, especially those experiments which are designed to investigate health effects of chemicals or radiation. Research supports the development of tests and assays by improving the design and analysis of experiments on (1) relative risk estimation in survival/sacrifice experiments and (2) screening and risk estimation for potential mutagens and carcinogens.

Energy. Data and anlyses are being provided in support of regional and national technology assessments of alternative energy technologies and energy fuel cycles. National and regional data bases and assessment methods are being developed and applied to assess the potential environmental, social, and economic effects of alternative energy technologies. Recent assignments include (1) an assessment of energy conservation strategies in the urban conservation sector, (2) an assessment of the response of the chemical and petroleum industries to recent environmental and energy legislation, (3) a technical review of the environmental residuals and resource needs associated with current energy systems, (4) an environmental control cost study of the indirect coal liquefaction technology, (5) an assessment of the health and safety impacts associated with small hydropower applications, and (6) an assessment of the environmental aspects of a district heating system supplied by cogeneration. Potential large-scale threats to public health and safety from activities related to various forms of energy production and use, especially related to terrorist acts, nuclear accidents, and nuclear war, are being anticipated and analyzed and countermeasures are being developed.

Instrumentation and Controls. New concepts, theories, devices, and advanced techniques which improve man's ability to measure or observe phenomena important to development of environmentally acceptable energy sources are being developed. The extraction of scientific information from pulse and curve shapes is being researched. The multidetector concept is being applied to optical and x-ray spectroscopy to develop new approaches to the analysis of organic and inorganic pollutants.

# LIFE SCIENCES SYNTHETIC FUELS PROGRAM

## INTRODUCTION

The Life Sciences Synthetic Fuels Program (LSSFP) has the objectives of supporting development of environmentally acceptable fossil fuel technologies, developing health and environmental information on principal issues, and conducting and validating health and environmental assessments. Key environmental and health concerns in coal conversion relate to: worker and public health and safety, solid waste management, air and water quality, and ecological and socioeconomic impacts. The program consists of two major components: a core research component coupled with an applied monitoring and testing component which is being implemented at several fossil energy facilities. The program emphasizes those processes for converting coal to synthetic fuels; however, the program also contains research in health and environmental aspects of coal combustion and oil shale.

The LSSFP provides a systematic framework for the interdisciplinary research being directed at fossil fuel technologies with the emphasis on developing data bases for use in assessing the environmental acceptability of these processes. The research program framework consists of the elements;

- o characterization, monitoring, and measurement -- development of sampling techniques, separations and fingerprinting methods, and surveillance instrumentation;
- o occupational toxicology -- identification and screening of potentially hazardous materials and assessment of dose-response relationships for chronic or acute exposures;
- o environmental fate and effects -- investigations of material dispersion, reconcentration, and impact on biological communities, and development of techniques for effluent and emission reduction; and
- o assessments -- optimization of plant and operations sitings through development and application of methods of risk analyses.

Field studies include (1) the Gasifier in Industry Program of DOE, which is concerned with demonstrating the integration of low-Btu gasification technology in various operational environments and (2) the H-Coal Pilot Plant, which will provide information on the liquefaction of coal. State-of-the-art technology for monitoring and testing will be applied in the several gasifier projects and in our H-Coal project.

ORNL staff have written a comprehensive study for gasifiers at the University of Minnesota at Duluth (UM-D), Pikeville, Kentucky, and the H-Coal Pilot Plants at Catlettsburg, Kentucky.

The assessment objective is to provide data and information that will enable DOE and other Federal agencies to arrive at judgments on the potential environmental and health impacts and consequent environmental acceptability of further commercialization of low-Btu gasification processes. The following discussions of the UM-D program illustrate the types of studies being undertaken.

Characterization, Monitoring, and Measurements

Numerous samples and analyses are taken by the environmental and health staff to characterize both the process streams and plant effluents and to assess the efficiency of environmental control devices. Process characterization provides information for control technology evaluation and for interpretation of biological and ecological test results; effluent characterization provides input to health effects considerations and guidance in ecological testing and environmental monitoring in an environment that is already subjected to industrial contaminants; and in-plant characterization provides for occupational health controls and correlations with potential occupational exposure situations. The sampling strategy provides for characterization of materials introduced into the process of intermediate or final products and of recycle or waste streams. Grab samples and samples classified by use of four special sampling trains will also be used in process and effluent characterization.

Personnel Protection and Occupational Toxicology

In the industrial hygiene program, area monitoring is used to indicate possible exposures, while personnel monitoring and dosimeters define the actual exposure. This monitoring program covers a variety of potential insults: noise, mercury vapors, heat, carbon monoxide, coal tar, dust, and a number of organic and inorganic compounds. The program is intended to identify potential health hazards in coal processing plants, thereby reducing employee exposures.

Two types of monitoring for potential exposures are provided. Area monitoring for CO, polynuclear aromatic hydrocarbons, dust, heat, noise, and various chemical stresses is carried out. Personnel monitoring, using filter and gas badge techniques, defines the actual exposure. Medical surveillance includes complete physical examinations of plant workers, with special attention to skin abnormalities.

The principal focus of the occupational toxicology component of the program is the testing of the by-product tars and primary effluents for potential effects on man. A two-level bioassay program is seeking answers to questions about the relative toxicity of by-products and effluents, toxicity variation with process conditions, and toxicity potential of fugitive emissions. At the first level, cellular bioassays are used to ascertain how relative toxicity varies with process changes, to screen for further testing, and to correlate with whole animal

effects. Level two, mammalian somatic toxicity tests, involves the use of whole animals to characterize the acute, subacute, and chronic toxicity of products and effluents. Only selected samples will be used initially in the more expensive toxicity tests, with selection based on the probability of direct or indirect human exposure and on current information of potential emissions.

Environmental Fate and Effects

Environmental area monitoring includes the collection and analyses of samples, operation of continuous monitors, and application of appropriate ecological toxicity tests. Information derived from these activities is used to characterize and quantify air, water, and solid effluents that may impact the immediate environs of the plant. If stack monitors indicate sufficient efflux of noncriteria pollutants (e.g., COS, $NH_3$, HCN), additional measures will be adopted to monitor for these pollutants. Water quality measurements will be limited to samples taken from wells for ash disposal. In the event of unusual plant operating conditions, liquid effluents and surface streams will be monitored. Gasifier ash will be leached, and the water samples and leachates will be analyzed for a variety of organic and inorganic constituents. Screening activities will be used, as appropriate, to test the toxicity, transport, degradation, and bioaccumulation characteristics of either whole effluent streams, selected chemical fractions, or specific model compounds.

Assessments

Site-specific assessments will be used to ensure a maximum integration and utilization of information developed by the program elements of sample collection, analytical characterization, biological and environmental testing, and occupational control and medical surveillance.

Analyses of potential impacts includes consideration of:

a. human health related assessments, including the industrial workers and the general public;
b. ecological related assessments, both terrestrial and aquatic systems in the site area; and
c. operational assessments, involving environmental control equipment, its efficiency and reliability, and occupational health control, and the engineering systems used to reduce fugitive emissions.

Information developed in these assessments will be combined with that from studies of several other low-Btu gasifiers, and will be used to investigate the potential impacts of anticipated industry growth.

## ORGANIZATION

The LSSFP involves researchers from eight ORNL divisions (Figure 8). The project areas can be defined as follows:

- o Chemical Characterization
- o Health and Safety
- o Biological Effects
- o Environmental Transport and Ecological Effects
- o Control Technology
- o Assessment and Siting
- o Information Support

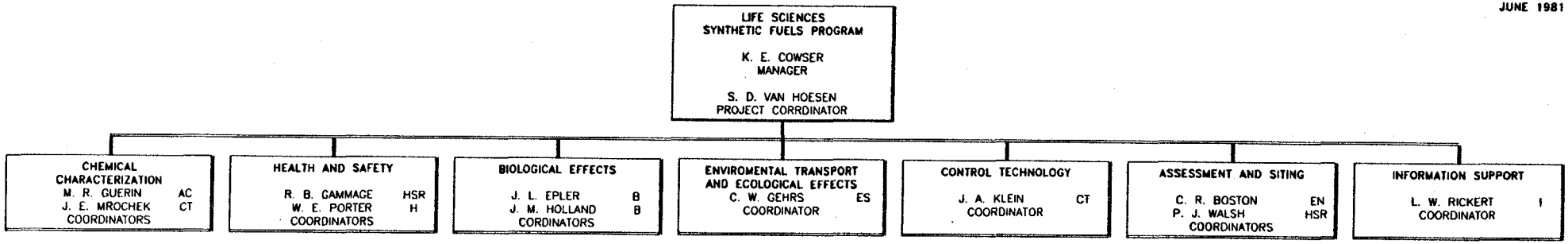
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Figure 8

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